30th ANNUAL CONFERENCE REPORT ON Cotton Insect Research and Control

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AGRICULTURAL
RESEARCH
SERVICE

IN COOPERATION
WITH 14
COTTON-GROWING STATES

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UNITED STATES
DEPARTMENT OF
AGRICULTURE

RESEARCH--THE BASIS OF PROGRESS

Cotton insect research contributes to more efficient cotton production and offers hope of further reducing production costs and increasing profits. A continuing research program is essential if a favorable position is maintained in the battle with cotton pests. The ability of pests to develop resistance to highly effective insecticides emphasizes the need for a program of basic and applied research. New concepts and methods of control can come only through research.

Basic or fundamental research on the bionomics, physiology, biochemistry, and behavior of insects, on the chemistry of insecticides, and on the physiology of the cotton plant is essential to the development of new concepts of cotton insect control. This research is essential before major breakthroughs can be achieved in developing insect-resistant cotton varieties, long-lasting systemic insecticides, and new concepts of control; in discovering effective attractants; in solving the insecticide resistance problem; and in making maximum use of biological control.

Future research output depends on the availability of highly trained personnel working in an atmosphere favorable to productive research. Those interested in the welfare of the cotton industry should encourage promising high school and college students to enter the field of professional entomology as teachers, research scientists, extension and survey entomologists, and field scouts.

COOPERATIVE EXTENSION--PROGRESS THROUGH EDUCATION

The Cooperative Extension Service in each State bridges the gap between the researcher and the grower by making the most recent research results available for practical use at the farm level. The goal of Cooperative Extension Service entomologists, as well as of research entomologists, is to contribute to more efficient cotton production by reducing production costs and increasing profits through better and more economical insect control. Cotton insect research is of value only when its findings are used by cotton growers.

The first step in bridging the gap is the joint development of cotton insect control recommendations which are published as Guides for Controlling Cotton Insects by the Cooperative Extension Service in each cotton-producing State. Entomologists and county agents of the Cooperative Extension Service then disseminate this information widely via farm magazines, newspapers, radio, television, and other educational aids.

Entomologists in the Cooperative Extension Service must have more than a thorough knowledge of cotton insects and their control. They must know how to present this information in a form that will be readily accepted and applied by growers. Young people with such aptitude, for example, those enrolled in 4-H clubs, should be encouraged to enter this phase of professional entomology.

PREFACE

This report has been prepared by specialists in research and control of cotton insects. It presents information of value to:

1. Industry in planning production programs.
2. State and Federal research workers in planning research programs.
3. Extension entomologists in developing insect control recommendations.
4. College and university teachers.
5. Consulting entomologists.

In utilizing the information presented in this report individuals should recognize their responsibility with regard to the impact of pesticides on man and on his environment. Wherever possible, control measures consistent with good cotton insect control and protection of the environment should be used. Control techniques other than insecticidal should be developed for use in the overall program.

Most of the reports of the committees and study groups that were appointed to review and evaluate the status of persistent pesticides recommended that provisions be made for the orderly reduction in the usage of persistent pesticides.

In responding to these recommendations certain registered use patterns have been canceled. These cancellations mean that farmers and other users often must exercise greater care and caution when protecting their crops with substitute insecticides. Some of these substitutes are far more hazardous to humans than the previously registered pesticides because of their much higher acute toxicity.

The registrations and recommendation of pesticides is under constant review and is subject to change as warranted. It is the responsibility of all who recommend and use pesticides to be aware of the current status of pesticides and to be guided by it in recommending or using pesticides.

THE FEDERAL ENVIRONMENTAL PESTICIDE CONTROL ACT OF 1972

The Federal Environmental Pesticide Control Act (FEPCA) of 1972 became law on October 21, 1972, revising the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) of 1947.

Some sections of the new act became effective immediately while others have deadlines for later enforcement, pending the establishment of regulations and development of Federal standards to guide States in implementing the legislation. Although provisions of the new act were to be implemented by October 1976, certain portions were extended for one year by amendment dated November 28, 1975.

Before registration may be granted for a pesticide product, the manufacturer is required to provide scientific evidence that the product, when used as directed, will (1) effectively control the pest(s) listed on the label, (2) not cause unreasonable effects on the environment, and (3) not result in illegal residues in food or feed.

Background.--The FIFRA was administered by USDA until the authority was transferred to the EPA when it was established in December 1970. The administering agency has authority to cancel a pesticide registration when the registered use of the product is in violation of the act or poses a serious hazard to humans or their environment. The registrant is entitled to appeal the cancellation notice through a process that can include public hearings and scientific advisory committees.

Suspension of a pesticide registration, unlike cancellation, halts interstate shipments immediately and is reserved for those products that present an imminent hazard.

The pesticide amendment to the Federal Food, Drug, and Cosmetic Act provides protection to consumers from harmful pesticide residues in food. The amendment requires that, where necessary to protect the public health, a tolerance or legal limit be established for any residues that might remain in or on a harvested food or feed crop as a result of the application of a chemical for pest control. Tolerances are based on chemical and toxicological data showing that the residues are safe for consumption.

The authority to establish tolerance levels was transferred from the Food and Drug Administration (FDA) of the Department of Health, Education, and Welfare to EPA in December 1970. The enforcement of tolerances remains the responsibility of the FDA.

Provisions of the New Law.--Some of the provisions of the 1972 act are:

*The use of any registered pesticide in a manner inconsistent with labeling instructions is prohibited, effective immediately. Civil and criminal penalties for misuse of pesticides are provided.

*Knowing violations of the act by farmers or other private applicators can result in fines of up to $1,000 or 30 days imprisonment, or both, upon criminal conviction. Second and subsequent offenses are subject to civil fines of up to $1,000 as well.

*Any registrant, commercial applicator, wholesaler, dealer, retailer, or other distributor, who knowingly violates the law, is liable to a criminal fine of up to $25,000 or one year in prison, or both, and to civil penalties of up to $5,000 for each offense.

*Pesticides must be classified for general use or restricted use by October 1976.

*The States will certify pesticide applicators for use of restricted pesticides. The act allows 5 years for development of certification programs. Federal standards for certification must be set forth by October 1973, and the States must submit their certification programs based on these standards by 1976. The State programs must be approved within 1 year of submission.

*The Administrator of EPA may issue orders stopping the sale, use, or removal of any product when it appears that the product is in violation of the act or the registration has been suspended and finally canceled. Products in violation of the act may also be seized.

*Pesticide manufacturing plants must be registered by October 1973.

*EPA is required to develop procedures and regulations for the storage and disposal of pesticide containers. They must accept, at convenient locations for disposal, pesticides which have had registrations suspended and then canceled.

*The Agency is authorized to issue experimental use permits, conduct research on pesticides and alternatives, and monitor pesticide use and presence in the environment.

*The owners of certain pesticides whose registrations are suspended and finally canceled are entitled to indemnification.

*States are authorized to issue limited registrations for pesticides intended for special local needs.

*States may impose more stringent regulations on pesticides than the Federal Government, except for packaging and labeling.

*The views of the Secretary of Agriculture are required to be solicited before the publishing of regulations under the act.

*Federal registration of all pesticide products, whether they are shipped in interstate or intrastate commerce, is required under the new act.

On November 28, 1975, President Ford signed Public Law 94-140 which further amends FIFRA. The amendments provide for:

*Formal consultation with the Department of Agriculture.

*Submission of certain proposed actions to a Scientific Advisory Committee.

*Submission of proposed and final regulations to the House and Senate Agriculture Committees for their information.

*Self-certification of private applicators under regulations established by the Administrator of EPA.

*Extension of the October 21, 1976 deadline to October 21, 1977.

The reader is encouraged to consult the closest regional office of the EPA for further information and details on the provisions and regulations of the FIFRA, as amended by the FEPCA of 1972.

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30th ANNUAL CONFERENCE REPORT ON COTTON INSECT RESEARCH AND CONTROL

Atlanta, Georgia, January 10-12, 1977

INTRODUCTION

This report of the 30th Annual Conference of State and Federal workers is concerned with cotton insect research and control. Research and extension entomologists and associate technical workers from 14 cotton-growing States, the United States Department of Agriculture, the National Cotton Council of America, and Cotton Incorporated met to review the research and experiences of the previous year and to formulate guiding statements for control recommendations in 1977.

The chief purpose of the Conference is to enable the exchange of information that may be useful in planning further research, survey, and extension work, and to make the results of research available to others.

The report presents information of value (1) to industry in planning production programs, (2) to State and Federal research workers in planning research programs, (3) to extension entomologists in bringing to the attention of growers and other interested groups the control recommendations for their States, (4) to teachers of entomology in the various colleges and universities, and (5) to consulting entomologists. It is also widely used in foreign countries in connection with the development of cotton insect control programs.

The Conference Report is available to anyone interested in cotton production. Copies may be obtained from Bioenvironmental Insect Control Laboratory, U.S. Department of Agriculture, ARS, Stoneville, MS 38776. It may be duplicated in whole or in part, but it should not be used for advertising purposes. No less than a complete section relating to one material or insect together with any supplemental statements should be copied.

Agreement on overall recommendations may be expected; however, complete standardization throughout the Cotton Belt is not possible. Details of recommendations will vary with the region or locality.

Cottongrowers in the respective States should follow the recommendations contained in the State Guides for Controlling Cotton Insects and the advice of qualified entomologist familiar with local problems.

Determining the species and abundance of various insects and the specific injuries inflicted upon the cotton plant is important in insect control. Knowledge of the life history and habits of the insects, the growth and fruiting characteristics of cotton plants, and the environmental relationships that exist between the plants and insects yields additional information basic to an evaluation of the economic insect situation involved. Each control measure used should be a part of an integrated control program, utilizing to the fullest extent wherever possible cultural, physical, mechanical, biological, legal, and natural controls. However, when the level of infestation of an insect or group of insects approaches the economic threshold, chemical control measures should be applied to prevent damage to the cotton crop. Insecticides, dosages, formulations, and timing schedules should be selected to solve existing problems without creating new ones.

Research results on cotton insect control obtained by the United States Department of Agriculture and the State experiment stations are extended to the cotton industry by the Cooperative Extension Service in each State. It is the responsibility of each individual farm operator to make decisions concerning the control of cotton insects. He may do this himself or he may delegate the job to someone else. (See "Determining the Need for Insecticide and Miticide Applications," p. 23).

In making recommendations for the use of insecticides, entomologists should recognize their responsibility with regard to hazards to the public. (See "Precautions in Using Insecticides and Miticides," p. 12).

The insecticide industry has a great responsibility to the cottongrower in making available adequate supplies of recommended materials that are properly formulated. Sales programs should be based on State or area recommendations.

Various "remedies" and devices, such as concoctions of unknown makeup, bug-catching machines, light traps, and other mechanical or electrical contrivances for controlling insects, have been put on the market through the years. Although some had slight value, most were less effective and more expensive than widely tested standard methods. Cottongrowers are urged to follow approved recommendations known to be of sound value.

CULTURAL PRACTICES

The development of resistance by cotton insects to some insecticides makes good cultural practices imperative. Certain cultural practices reduce and under some conditions may even eliminate the need for insecticides. Several of these practices can be followed by every cottongrower whereas others are applicable only to certain areas and conditions. Growers following these practices should continue to make careful observations for insects and apply insecticides only when needed.

Early Stalk Destruction

The boll weevil resistance problem emphasizes the urgent need for early destruction of cotton stalks. The destruction or killing of cotton plants as early as possible before the first killing frost prevents population buildup and reduces the overwintering population. The earlier the weevil population is deprived of its food supply the more effective this measure becomes. Early stalk destruction, especially over communitywide or countywide areas, has greatly reduced the boll weevil problem the following season, especially in the southern part of the Cotton Belt.

Early stalk destruction and burial of infested debris are generally the most important practices in pink bollworm control. Modern shredders facilitate early stalk destruction and complete plowing under of crop residues. The shredding operation also kills a high percentage of pink bollworms left in the field after harvest. The flail-type shredder is recommended over the horizontal rotary type for pink bollworm control. Plowing under crop residue as deeply as possible after the stalks are cut will further reduce survival of the pink bollworm. The use of these machines should be encouraged to control both the boll weevil and pink bollworm. Early stalk destruction can also reduce the potential number of overwintering bollworms and tobacco budworms.

Stub, Volunteer, or Abandoned Cotton

Stub, volunteer, and abandoned cotton contributes to insect problems because the stalks and undisturbed soil provide a place for insects to live through the winter. This is especially true for the cotton leafperforator, the pink bollworm, and the boll weevil. Volunteer cotton is also the principal winter host for the leaf crumple virus of cotton in the southwestern desert areas and for its whitefly vector. All cotton plants should be destroyed soon after harvest.

Planting

Uniform planting of all cotton within a given area during a short period of time is desirable. A wide range in planting dates extends the fruiting season, which tends to increase populations of the boll weevil, pink bollworm, and possibly other insects. Planting during the earliest optimum period for an area also makes early stalk destruction possible.

Skip-Row Planting

The practice of skip-row planting has changed some of the aspects of insect control on cotton. Insects and spider mites that feed on weeds allowed to grow in these strips may move into the cotton when such weeds are destroyed by cultivation. The skip-row practice necessitates modification of ground application equipment. Applications by airplane become more expensive since the entire field must be treated and only a part of it is planted to the crop.

Varieties

Varieties of cotton that bear prolifically, fruit early, and mature quickly may set a crop before the boll weevil and other insects become numerous enough to require prolonged treatment with insecticides. This is especially true when other cultural control practices are followed. Growers should plant varieties recommended for their particular area. Cotton breeders are working with entomologists to develop varieties resistant to several cotton insects.

Soil Improvement

Fertilization, crop rotation, and plowing under of green manure crops are good farm practices and should be encouraged. The increased plant growth, which usually results from these practices, may also prove attractive to some pests, necessitating closer attention to their abundance and control. The potential higher yields will give greater returns from the use of insecticides. Overfertilization, especially with nitrogen, may unnecessarily extend the period during which insecticidal protection is necessary. Likewise, undergrowth and delayed maturity may result from nutritional or moisture imbalance, but these should not be confused with insect damage.

The fact that a number of insects and spider mites attack legumes and then transfer to cotton should not discourage the use of legumes for soil improvement or crop rotation. Insect pests may be controlled on both crops.

Other Host Plants of Cotton Pests

Cottonfields should be located as far as is practicable from other host plants of cotton insects. Some control measures should be applied to other hosts to prevent migration to cotton. Thrips breed in onions, potatoes, carrots, legumes, small grains, and some other crops. They later move in great numbers into adjacent or interplanted cotton. Beet armyworms, garden webworms, lygus bugs, stink bugs, variegated cutworms, western yellowstriped armyworms, and other insects may migrate to cotton from alfalfa and other plants. The cotton fleahopper migrates to cotton from horsemint, croton, and other weeds. Spider mites spread to cotton from many weeds and other host plants adjacent to cottonfields.

Overwintering Areas

The boll weevil hibernates in well-drained, protected areas in and near cottonfields. Spider mites overwinter on low-growing plants in or near fields. Pest-breeding areas of weeds along turnrows and fences or around stumps, and scattered weeds in cultivated fields should be eliminated with herbicides, cultural, or other methods. General burning of ground cover in woods is not recommended. Since ground cover and weeds serve as hibernating sites for many parasites and predators, the detrimental effects of indiscriminate destruction of weeds by burning and tillage on beneficial insects are obvious.

Seed cotton scattered along turnrows, loading areas, and roadsides serves as a source of pink bollworm carryover to the next crop. Care should be taken to see that these areas are cleaned up. To minimize this hazard, trucks, trailers, and other vehicles in which the seed cotton is being hauled to the gin should be covered.

Gin-plant sanitation should be practiced to eliminate hibernating quarters of the boll weevil and the pink bollworm on such premises. In areas where pink bollworms occur, State quarantine regulations require that gin trash be run through a hammer mill or fan of specified size and speed, composted, or given some other approved treatment.

Quarantine regulations require certification of mechanical cotton pickers and strippers moving from pink-bollworm-infested to noninfested areas.

ATTRACTANTS

BOLL WEEVIL--In the 1950's an observation was made at the ARS Stoneville, Mississippi Cotton Insects Laboratory that the female boll weevil sought the male rather than the usual procedure in most insects of the male seeking the female. This was verified in laboratory studies at the Boll Weevil Research Laboratory in the mid-1960's, and the attractant was identified and synthesized. It was named grandlure. It is now commercially available and is widely used in migration, survey, and detection procedures. Hopefully it will be registered in the future for use in population management and eradication programs. A trap baited with grandlure was developed to capture female boll weevils. Grandlure is also an aggregant, as at certain times of the year males as well as females are attracted to it. Traps baited with grandlure and placed along the edges of cottonfields capture tremendous numbers of overwintered boll weevils.

In the Pilot Boll Weevil Eradication Experiment conducted in south Mississippi and in adjoining areas of Louisiana and Alabama in 1971-1973, traps baited with grandlure and installed at two per acre around field edges were used as one of the suppression measures in the core or eradication area. Trap crops consisting of cotton planted some 2 weeks earlier than that of the grower cotton were baited with grandlure at 100-foot intervals. Plants in the trap crops were treated in-furrow at planting with aldicarb, a highly effective systemic insecticide, and sidedressed with it at early squaring to kill overwintered weevils attracted to them. The trap crops were treated with methyl parathion during periods when the aldicarb treatment was considered not to be effective. Very few weevils were found in the grower cotton before it began to fruit. Even after grower cotton began to square, weevils continued to be attracted to the trap crops, as evidenced by the collection of sterile males released in the grower cotton being collected in the trap crops. The development of in-field traps, those that can be used within fields without interfering with cultivation, baited with grandlure has potential as a tool in population suppression or elimination programs.

Alternate strips of cotton within fields comprising about 10 percent of the acreage baited with grandlure may be used to attract overwintered boll weevils, which then are killed with insecticides applied to the baited strips. If weevil populations are low, such treatments may prevent injurious infestations in the remainder of the field for the season.

In the early years considerable unsuccessful effort was expended in developing attractants from cotton plants for use in controlling the boll weevil. Interest in boll weevil attractants from the cotton plant was revived by researchers in the 1960's. Water and chloroform extracts of cotton plant parts were attractive. A powerful arrestant and feeding stimulant was found in water extracts of all cotton parts and square components tested. A feeding deterrent was found in the calyx of an alternate host, _Hibiscus syriacus_. However, the chemistry of the arrestant and attractant compounds in the cotton plant is so complex that chemists have been unable to identify and synthesize all of them for use in control, suppression, or survey programs. Cottonseed oil baits have been used with the _Heliothis_ nuclear polyhedrosis virus to insure ingestion of the virus by the bollworm complex.

PINK BOLLWORM--It was determined in the mid-1960's that the female pink bollworm moth emitted a substance that was attractive to males. Chemists identified and synthesized the substance and named it propylure. Unfortunately, propylure, though attractive to males in the laboratory, failed to perform in the field. Apparently, something was missing in the synthesized compound. A somewhat structurally related compound was found to be attractive to males. It was named hexalure and was widely used in the West in survey and detection operations. Though not as attractive as the natural pheromone, hexalure was sufficiently attractive to be used to bait traps so that use of live females was obviated. An intensive effort was made by ARS chemists to identify and synthesize the pheromone. However, progress was slow, and in late 1973 researchers at the University of California, Riverside, identified and synthesized the compound. ARS chemists verified their findings. It has been named gossyplure. It has considerable potential for use in survey, detection, and population suppression programs. It has been used in large field experiments as a confusant. When gossyplure is applied to a field of cotton, the male then cannot locate the female.

TOBACCO BUDWORM AND BOLLWORM--Females of the tobacco budworm and bollworm produce powerful sex pheromones or sex attractants to lure males of the respective species for mating. Research has continued since 1963 on these pheromones, with the ultimate goal of producing synthetic materials that could be used for population survey and suppression.

The pheromone of the female tobacco budworm, virelure, was identified and synthesized. A crude extract of the pheromone from females had very short activity, and a similar problem has been found with the synthetic material. Research is currently directed toward development of a stable formulation of the synthetic pheromone to give long-term activity in the field.

A similar attractant has recently been discovered for the bollworm; however, it is as yet uncertain whether the synthesized compound is the natural sex pheromone.

Once stable formulations of the pheromones of the two species are devised, the development of population suppression schemes will become possible. Among the methods suggested for use of these materials are eliminating males by trapping or dispensing the attractant on an insecticide-treated substance, luring the males to a substrate treated with chemosterilants, or saturating an environment with the pheromone, thus interfering with the mating orientation of the males. Development of methods for using the pheromones in traps to anticipate outbreaks of the pests for timing of insecticide applications appears promising.

A related approach has been the search for chemicals that will disrupt the chemical communication between sexes. Researchers have shown that the attractiveness of female tobacco budworms is greatly reduced if certain organic chemicals are released into the environment. However, results of these studies are preliminary.

Researchers have reported that the male tobacco budworm when preparing to mate with a female produces a substance that suppresses her emission of the sex pheromone, but no work has been done on isolating the active agent. It is possible that such substances would be useful in combination with some of the previously noted techniques.

Results of recent research have shown that certain egg and larval parasites of *Heliothis* spp. are attracted to the host by host-seeking stimulants named kairomones.

TARNISHED PLANT BUG--In the early 1970's a researcher at the Stoneville, Mississippi, Bioenvironmental Insect Control Laboratory found that the female tarnished plant bug produced a substance that was attractive to males. Research to identify the substance is underway.

GENETIC CONTROL

Research on genetic control of cotton insects has centered on the sterile-insect release approach that was so successful against the screwworm fly, *Cochliomyia hominivorax* (Coquerel). In this approach large numbers of insects are reared and exposed to ionizing irradiation or to chemosterilants to induce sterility; then they are released among native populations at sufficient ratios to insure a high proportion of sterile matings. Development of this technique includes devising methods for rearing and sterilizing large numbers of insects with minimum effect on their competitiveness in securing mates, for shipping them from the rearing facility to release sites and releasing them so that they disperse among the native population, and for monitoring the

effectiveness of the program. Frequently, preliminary application of other population reduction measures such as insecticides are needed to reduce native populations to levels low enough so that an effective overflooding ratio can be achieved.

BOLL WEEVIL--Much research has been conducted on sexually sterilizing the boll weevil. Effective doses of gamma irradiation reduce competitiveness and result in high mortality. Similar results were obtained with some of the chemosterilants. Finally, workers at several laboratories found that busulfan could achieve sterility in the male when incorporated in the adult diet for a 6-day feeding period. The long feeding period was a disadvantage, and another shortcoming of busulfan was that it did not sterilize the female. Thus, in the Pilot Boll Weevil Eradication Experiment, the weevils had to be sexed for use of the sterile-male component. Sexing has to be done manually and is therefore laborious and costly. In an elimination program, the cost of sexing would be prohibitive. An intensive effort was then made to find a chemosterilant effective against both sexes. A combination of a 4-day feeding of busulfan-treated diet to adults plus a few hours of fumigation with hempa appeared to satisfactorily sterilize both sexes. However, research continued because the long holding and feeding period needed to be reduced or eliminated.

An insect growth regulator, diflubenzuron, has been shown to have exciting possibilities. It is not a mutagenic agent and does not sterilize males. However, treatment of females will inhibit egg hatch for a period of 1 to 2 weeks. It should be possible to completely sterilize both sexes by treating gamma-irradiated weevils with diflubenzuron.

Use of fractioned doses of gamma irradiation applied at 4-hour intervals also appears to be promising. Chances of the problem being solved before an elimination program is undertaken are good.

BOLLWORM AND TOBACCO BUDWORM--A great deal of research has been done on methods of sterilizing *Heliothis* spp. and on the effects of various aspects of sexual competitiveness. Gamma irradiation has been pursued most extensively because it is relatively easy to use and presents minimum environmental hazards when proper equipment is used.

A limited field test of this method against the bollworm conducted on St. Croix, U.S. Virgin Islands, in the early 1970's, was only partially successful because problems with rearing interfered. More extensive tests were conducted on the same island in 1972-74. The results of these tests indicated that released mass-reared insects, whether irradiated or not, competed poorly for native mates, especially the males. However, populations of the bollworm were reduced to very low levels because the sterile females mated earlier in the night than the native females. The sterile males were essentially noncompetitive with the native males. Both types of males were ready to mate at any time of night; therefore, the native males mated with sterile females when the latter were ready. When the native females began mating at the later hour, the available native males had already mated and, as a result, the sterile males mated with these females with little competition. Since populations of bollworms were limited to a few small plantings of corn on the island, relatively high ratios of sterile to native insects were achieved, and the population could be manipulated rather easily. It is questionable whether this procedure could be used on a large scale.

The test with the tobacco budworms showed that the sterile males were about 25 percent as competitive for mates as native ones. This resulted from

the mass-rearing conditions and irradiation. A lack of synchrony in mating times of sterile and native insects of both sexes was noted, thus making the system used against the bollworm ineffective in this case. Also, populations of the tobacco budworm were much larger and more widely distributed than those of the bollworm, with the result that the sterile-to-native insect ratios were generally too low (5 to 1) to have much impact on the native populations when the competitiveness problem was considered.

Research is continuing on development of this method for use against the tobacco budworm, with emphasis on defining and overcoming problems related to the poor competitiveness of the sterile insects.

Hybrids have been produced in the laboratory by crossing *Heliothis virescens* and *H. subflexa*. Hybrid males from these crosses were sterile and the females were fertile. These females, when mated to normal *H. virescens* males, produced sterile males and fertile females through subsequent backcross generations. Male sterility has persisted through 40 backcross generations. If this technique can be perfected, it is potentially possible to suppress or eliminate populations through male sterilization by releasing these females into the natural population.

PINK BOLLWORM--Gamma irradiation for sterilizing pink bollworms has been under study for some time. Research continues, and doses have been reduced to 20 krd, which has improved competitiveness of treated males with nonsterile males for females. The pink bollworm has been mass-reared at the Methods Development Laboratory, Animal and Plant Health Inspection Service (APHIS), USDA, Phoenix, Arizona, since 1967. Migrants from the Imperial and Coachella Valleys have been detected in relatively low numbers in certain localities of the San Joaquin Valley in California each year since 1967. Sterile moths have been released in these localities each year beginning in 1968. Approximately 100 million were released annually from 1970 through 1973, but rearing problems reduced the numbers released in 1974. The 100 million release number was again attained in 1975 and 1976. The releases apparently have prevented establishment of infestations in this important cotton-producing valley. Such treatment must continue until the pest is eliminated or reduced to very low levels in the Coachella and Imperial Valleys so they no longer will provide migrants to the San Joaquin Valley

Beginning in November 1972, sterile moths have been released in the off cotton seasons in the extreme southern tip of Florida to suppress pink bollworm populations in wild cotton growing in the area. For many years population suppression was attained by manual destruction of wild cotton plants. This was a costly and difficult task, as the cotton was impossible to eradicate with this procedure. The sterile-male release technique hopefully will suppress populations to the extent that the pink bollworm cannot migrate to the northern part of the State where cotton is grown.

If elimination of the pink bollworm is undertaken in the future, the sterile-male release technique will no doubt be a major component in the program.

REARING

Research on cotton insects was hampered for many years because of difficulties encountered in rearing them in the laboratory. It was difficult, as well as expensive, to rear insects in needed numbers on their hosts. Major breakthroughs in research could only come with ability to mass rear the various insects on artificial diets.

PINK BOLLWORM--The first phytophagous insect to be reared on an artificial diet was the pink bollworm reared in the early 1950's at the College Station, Texas Cotton Insects Research Laboratory. The artificial diet developed for this insect has served as the basic diet for many phytophagous insects now being mass reared in the laboratory. The pink bollworm was mass-reared in tremendous numbers in the late 1960's and 1970's in the USDA's Animal and Plant Health Inspection Service Laboratory in Phoenix, Arizona. The insects were made sexually sterile and several million per week were released in the San Joaquin Valley of California at selected locations where migrant moths had been captured. The releases have apparently prevented the establishment of infestations by occasional migrants from the Imperial and Coachella Valleys. In the off cotton season sterile-moth releases were made for several years to wild cotton in the southern tip of Florida for suppression of pink bollworm populations on that host. For many years populations were suppressed by manual destruction of wild cotton plants, which was a costly and almost impossible task. The new technique was made possible through the development of mass-rearing procedures for the insect.

BOLL WEEVIL--In the early 1960's boll weevils were reared on artificial diets at the College Station, Texas, Cotton Insects Research Laboratory. Improvements in rearing were made at that laboratory and at the Baton Rouge, LA and Florence, SC laboratories. Progress in mass rearing the insect was made with the establishment of the Boll Weevil Research Laboratory on the Mississippi State University campus in 1962. After it became apparent that the insect could be reared in sufficient numbers, it was deemed that a Pilot Boll Weevil Eradication Experiment should be conducted to determine whether it was technologically and operationally feasible to eradicate the boll weevil. With an appropriation of more than $0.5 million from the Mississippi Legislature, the Robert T. Gast Rearing Laboratory was built on the Mississippi State University campus. Problems with the rearing facility, as well as with rearing procedures, prevented production of the numbers of insects needed for sterile-male releases in the experiment. However, the facility made a significant contribution to the success of the experiment and is expected to make an even greater contribution if elimination of the insect from the United States is undertaken. The rearing procedure has been automated and the facility is expected to provide needed numbers for the Boll Weevil Eradication Trial when it is initiated in North Carolina and Virginia.

BOLLWORM--Diets and techniques for rearing the bollworm also were developed at the College Station laboratory. Though small cultures have been reared at several laboratories, the major thrust in mass rearing has been done at the ARS Southern Grain Insects Laboratory at Tifton, Georgia. A prototype machine for mass rearing the insect has been developed at this laboratory.

TOBACCO BUDWORM--Techniques for mass rearing the tobacco budworm were developed at the Brownsville, Texas, ARS Laboratory in the late 1960's and early 1970's. Production was stabilized at about 60,000 pupae per day. Pupae were furnished from this laboratory for the sterile-male release study conducted on St. Croix, U.S. Virgin Islands, in the early 1970's. In addition, moths were reared for several years for the identification of the sex pheromone emitted by the female. Chromatographic analysis indicated it to be a multiple component system. The sex pheromone was isolated, purified, identified, and synthesized early in 1974.

LYGUS BUGS--*Lygus hesperus* and *L. lineolaris* have been reared on

artificial diets. However, techniques for mass rearing them on these diets have not yet been developed.

SALTMARSH CATERPILLAR--The saltmarsh caterpillar, *Estigmene acrea* (Drury) has been reared on the wheat germ diet at the College Station, Texas Cotton Insects Research Laboratory and has been mass-reared at the Tucson, Arizona Biological Cotton Insect Control Laboratory.

BENEFICIAL INSECTS--The green lacewing has been reared in the laboratory on an artificial diet, and some progress has been made in mass rearing it on this diet. Some progress has been made in rearing *Campoletis perdistinctus* and *Micropletis senorensis*, parasites of *Heliothis* spp., on artificial diets.

BIOLOGICAL CONTROL OF COTTON INSECTS

Predators, parasites, and diseases play an important role in the control of insect pests of cotton. Cotton pest control programs should maximize the role of natural enemies by utilizing insecticides, cultural practices and other agents and techniques in augmentative ways. The key role of naturally occurring biological control agents must not be ignored in modern pest control programs. Wherever possible, an attempt should be made to evaluate the role of beneficial insects in the field. Some predaceous and parasitic insects of prime importance follow.

Predators

HEMIPTERA--*Orius insidiosus* and *O. tristicolor*, often called minute pirate bugs or flower bugs, are voracious predators of eggs and first-instar larvae of the bollworm, thrips, and other small insects. Populations often build up in such crops as corn and grain sorghum. Big-eyed bugs, *Geocoris pallens*, *G. punctipes*, and *G. uliginosus*, are common predators of eggs and small larvae of the bollworm as well as other Lepidoptera, mirids, and aphids. Damsel bugs of the genus *Nabis* are efficient predators of a wide range of prey, including mirids, leafhoppers, aphids, and eggs and larvae of Lepidoptera. They attack bollworms as large as the second instar. Assassin bugs, particularly the genus *Zelus*, feed freely on eggs and larvae of Lepidoptera, including bollworm, tobacco budworm, and cabbage looper. These bugs are usually less abundant in cottonfields than those referred to previously. *Podisus maculiventris* is a common stink bug that preys on large bollworms and other caterpillars.

NEUROPTERA--Larvae of green lacewings, *Chrysopa* spp. are important predators of eggs and small larvae of bollworm and other Lepidoptera and of many soft-bodied insects.

COLEOPTERA--Ground beetles of the family Carabidae have considerable potential as predators in the cottonfield, but knowledge is lacking on the habits and factors affecting abundance of the many species. Lady beetles (Family Coccinellidae) are common predators in cottonfields. The large species, including *Coleomegilla maculata*, *Hippodamia convergens*, and *Coccinella novemnotata*, feed on eggs and small larvae of bollworm and other Lepidoptera and on aphids. Some smaller species in the genus *Scymnus* and all *Stethorus* spp. are primarily predators of mites. *Collops* beetles (Malachinnae in the family Melyridae) are often very abundant in cotton. They reportedly feed on the eggs and small larvae of the bollworm and other lepidopterous species.

DIPTERA--Many families contain species that are predaceous as adults or larvae. Best known as predators in cottonfields are the larvae of syrphid

flies that prey primarily on aphids.

HYMENOPTERA--Ants, family Formicidae, include many predaceous species. *Iridomyrmex pruinosus* is a regular predator of bollworm eggs. Paper-nest wasps, *Polistes* spp., and solitary wasps of the genera *Zethus*, *Eumenes*, *Rygchium*, and *Stenodynerus* provide their young in the nests with lepidopterous larvae. Wasps of the genus *Sphex* nest in the ground and provide their young with grasshoppers and related insects.

SPIDERS--All spiders are predaceous, and many species are common in cottonfields. Orb weavers capture many moths in their webs. Wolf spiders and lynx spiders capture moths and other insects. Larvae and adults of the bollworm and boll weevil are among the prey of jumping spiders.

Parasites

Numerous species of hymenopterous parasites of several families are of great value in the biological control of most pests of cotton. These parasites vary tremendously in size, behavior, ecology, and host preference. Within their ranks, however, effective or potentially effective parasites of nearly every developmental stage, egg through adult, of the majority of cotton pests may be found. Many of them occur naturally in great numbers in certain geographical areas. Some are now and many will eventually have to be augmented in the field by habitat management or mass-release techniques so as to concentrate their populations at the time and in the place required for most effective control.

Flies of the family Tachinidae are parasites primarily of larvae of Lepidoptera and Coleoptera. Several species are of value as parasites of cotton pests and should be examined with the same goals in mind as those mentioned above; that is, augmentation through laboratory or field practices.

Native predators and parasites are often highly effective against aphids, the bollworm, beet armyworm, tobacco budworm, cabbage looper, cotton leafworm, cotton leafperforator, cutworm, lygus bugs, saltmarsh caterpillar, spider mites, whiteflies, and certain other pests. Diversified crops and uncultivated areas serve as refuge and reservoir areas for predators and parasites and, unfortunately, for some pests.

Releases of large numbers of green lacewing larvae in field experiments in Texas gave control of heavy infestations of bollworms. Augmentation of food for lacewings has shown promise in California experiments. Releases of two species of introduced parasites have shown promise for control of the pink bollworm. However, much additional research is needed to develop such techniques into practical control measures. In addition, there are exotic species of predators and parasites of potential value in controlling both native and introduced cotton pests in the United States. Additional research is needed to locate and introduce them, and to evaluate their potential in pest control.

Diseases

Naturally occurring outbreaks of polyhedral viruses sometimes substantially reduce bollworm, tobacco budworm, cabbage looper, and cotton leafworm populations. These viruses can be produced on hosts mass reared on artificial diets. Their use is discussed on page 34. *Bacillus thuringiensis* is a naturally occurring insect pathogen that is produced commercially (see p. 30).

CHEMICAL DEFOLIATION AND DESICCATION AS AN AID TO COTTON INSECT CONTROL

Chemical defoliation and desiccation of cotton aid in the control of many cotton insects. These practices check the growth of the plants and accelerate the opening of mature bolls, reducing the damage and the late-season buildup of boll weevils, bollworms, tobacco budworms, and pink bollworms that would otherwise remain to infest next year's crop. They also prevent or reduce damage to open cotton by heavy infestations of the cotton aphid, the cotton leafworm, and whiteflies. However, defoliants and desiccants should not be applied until all bolls that are to be harvested are mature, if losses in yield and quality are to be avoided. Stalks should be destroyed and other cultural practices followed (discussed under "Early Stalk Destruction," p. 2).

Guides for the different defoliants and desiccants are issued by the Cooperative Extension Services of the various States. They contain information concerning the influence of plant activity, stage of maturing, and effect of environment on the efficiency of the process, and give details relating to the various needs and benefits. They explain how loss in yield and quality of products may be caused by improper timing of the applications. Local and State recommendations should be followed.

PRODUCTION MECHANIZATION IN COTTON INSECT CONTROL

Increased mechanization improves the efficiency of cotton production, including insect control. High-clearance sprayers and dusters and aircraft have proved very useful and satisfactory for the application of insecticides and defoliants, especially in rank cotton. Tractors also enable the grower to use shredders, strippers, mechanical harvesters, and larger, better plows--all of which help in the control of the pink bollworm and, to some extent, the boll weevil.

The flaming operation for weed control is of questionable value in insect control.

Mechanical harvesting with spindle-type pickers may result in leaving more infested cotton in the field than handpicking, thus increasing the potential overwintering pink bollworm population. On the other hand, the use of strippers to harvest the crop is highly desirable from the standpoint of pink bollworm control, because all open bolls are stripped from the plants and are transported to the gin where a high percentage of the larvae are killed in the ginning process.

Stalk shredders not only destroy certain insects, particularly the pink bollworm, but enable the cottongrowers over wide areas to destroy the stalks before frost and thereby stop the development of late generations of this insect, and the boll weevil, bollworm, and tobacco budworm.

The increased use of mechanized equipment for cotton production has resulted in large acreages of uniform, even-age stands in some areas. These factors tend to simplify cotton insect control. Hibernation quarters in or immediately adjacent to the fields are frequently eliminated by these modern cultivation practices.

PRECAUTIONS IN USING INSECTICIDES AND MITICIDES

Hazards and precautions in the use of insecticides and miticides are discussed in this section. All insecticides, of course, are toxic. On the

other hand, when the enviable safety record associated with the use of many millions of pounds of insecticides on cotton annually is considered, it becomes evident that if common sense precautions are observed, insecticides can be used with relative safety. This applies to the operator, the farmworker, and the cotton checker; to fish and wildlife; to honey bees; to our food and feed supply; and to the public in general.

Problems involving hazards to man, domestic animals, crops, fish, beneficial insects, and wildlife have been intensified by the increased use of insecticides for control of cotton insects. The precautions, recommended amounts, and registration numbers are given on labels of all materials legally offered for sale. <u>These materials should not be used unless the user is prepared to follow directions on the labels</u>.

In handling any insecticides, avoid contact with skin and inhalation of dusts, mists, and vapors. Wear clean, dry clothing and wash hands and face before eating or smoking. Launder clothing daily.

Avoid spilling the insecticide on the skin and keep it out of the eyes, nose, and mouth. If any is spilled, wash it off the skin immediately with soap and water. If you spill it on your clothing, remove clothing immediately and wash the contaminated skin thoroughly. Launder clothing before wearing it again. If the insecticide gets in the eyes, flush with plenty of water for 5 minutes and get medical attention.

Insecticide injury to man may occur through skin absorption or by oral or respiratory intake. Some solvents used in preparing solutions or emulsions are flammable, and most of them are toxic to some degree. In considering the hazards to man, it is necessary to distinguish between immediate hazards (acute toxicity) and cumulative hazards (chronic toxicity).

Insecticides used on cotton must be handled with care at all times and in all forms. The physiological activities of organophosphorus compounds in both insects and warmblooded animals are primarily inhibition of the cholinesterase enzyme. Initial or repeated exposure to them may reduce the cholinesterase level to the point where symptoms of poisoning may occur. These symptoms include headache, pinpoint pupils, blurred vision, weakness, nausea, abdominal cramps, diarrhea, and tightness in the chest. The symptoms may occur without forewarning. Applicators and handlers of these chemicals should be thoroughly aware of and familiar with the symptoms and the need to seek medical attention.

The toxicity of experimental compounds suggested for further testing may not be well known. Extreme precautions should be observed in their use until more information is available concerning their toxicity.

Formulations that have been accepted by the Environmental Protection Agency under experimental permits are required to show prominently on the front panel of the label "<u>For Experimental Use Only</u>" and should be utilized only for such purposes. According to the Federal Environmental Pesticide Control Act of 1972, pesticides registered under an "Experimental Permit" must not be used contrary to the provisions of the permit. Use contrary to the provisions of the permit constitutes a violation of the Act and is a punishable offense.

The following insecticides can be used without special protective clothing or devices, although malathion may be absorbed through the skin and inhaled in harmful amounts. In all cases, follow the label precautions.

acephate	dicofol
<u>Bacillus thuringiensis</u>	malathion

chlorobenzilate
sulfur
trichlorfon

The following insecticides can be absorbed directly through the skin in harmful quantities. When working with these insecticides in any form, take extra care not to let them come in contact with the skin. Wear protective clothing and respiratory devices as directed on the label.

chlorpyrifos
chlordimeform
diazinon
dimethoate
endosulfan
ethion
methidathion
naled
propargite
toxaphene

The following chemicals are highly toxic and may be fatal if swallowed, inhaled, or absorbed through the skin. These highly toxic materials should be applied only by a person who is thoroughly familiar with their hazards and who will assume full responsibility for proper use and comply with all the precautions on the labels.

aldicarb
azinphosmethyl
carbophenothion
demeton
dicrotophos
disulfoton
endrin
EPN
methamidophos
methomyl
methyl parathion
monocrotophos
parathion
phorate
phosphamidon

Preventing skin absorption--Many insecticides are almost as toxic when in contact with the skin as when taken orally. Such contact may occur through spillage or the deposition of fine mist or dust during application of insecticides.

With the exception of aerosols, agricultural sprays and dusts have relatively large particles. When such particles are inhaled, they do not reach the lungs but are eventually brought into the throat and swallowed.

Skin absorption constitutes a major route of entry, and yet it is the source of insecticide injury most likely to be ignored. Liquid concentrates are particularly hazardous. Load and mix them in the open. If you spill a concentrate on your skin or clothing, remove contaminated clothing immediately and wash the skin thoroughly with soap and water. Launder clothing before wearing it again. Contaminated shoes are a serious hazard. Launder work clothes and change shoes daily. When recommended, wear natural or other suitable rubber gloves while handling highly toxic compounds. Have a change of clothing and soap and water at hand in the field. Bathe at the end of the work period.

Preventing oral intake--Keep food away from direct contact with all insecticides and also keep it away from the possible fumigant action of volatile chemicals. Wash exposed portions of the body thoroughly before eating or drinking. Do not smoke or otherwise contaminate the mouth area before washing the face and hands. Do not measure or store pesticides in containers that might be mistaken for food containers. Store pesticides only in the original containers with legible labels attached.

Preventing respiratory intake--If called for on the label, wear a respirator or mask of a type that has been tested and found to be satisfactory for protection against the particular insecticide used. Decontaminate the respirator between operations by washing the respirator and replacing felts or cartridges, or both, at recommended intervals of use.

Information on respirators certified for protection against insecticides may be obtained from the National Institute for Occupational Safety and Health, Testing and Certification Laboratory, 944 Chestnut Ridge Road, Morgantown, West Virginia 26505.

Determine blood cholinesterase levels--Regular users of organophosphorus compounds should have their blood cholinesterase levels checked before the start of a season's work and periodically thereafter. It is advisable to have on hand a small supply of 1/100-grain atropine tablets for emergency use as prescribed by medical authorities in case of poisoning. Do not use atropine as a preventive for organophosphorus poisoning. Another antidote for phosphorus poisoning is 2-PAM which must be administered under the supervision of a physician. Be sure the local physician is familiar with treatment and has the antidote on hand before large-scale application is begun. Speed of proper treatment is essential. (See "Information on Poison Control Centers," p. 16).

Carbamates are also inhibitors of cholinesterase, and regular users of these chemicals should be checked and treated as above, with one exception: 2-PAM and other oximes are not recommended. These compounds are referred to as "rapidly reversing inhibitors of cholinesterase." The reversal is so rapid that unless special precautions are taken measurements of blood cholinesterase of human beings or other animals treated with these compounds are likely to be inaccurate and always in the direction of appearing to be normal. The blood cholinesterase inhibition should be measured by a technique that minimizes reactivation.

Disposal of excess materials and used containers--Excess dust or spray materials should be buried. The burial sites for excess insecticides, wastes, equipment washings, and containers should be selected with care and so situated that contamination of ground water does not occur. When possible, growers should carry their empty insecticide containers to a sanitary landfill-type dump and have them buried. Inform the dump operator of the nature of the residues in the containers. Some States require that they be buried at a designated place. Empty metal containers should be smashed beyond possibility of reuse and buried.

Handling materials in the field--Metal containers of emulsifiable concentrates carried to the field should be placed in the shade. Agitation of closed containers that have been left in the sun can result in pressure buildup in the container--with a resultant exploding of the contents when the top is removed.

Storage of insecticides--Insecticides should be stored in a separate, fireproof building to avoid contamination of food, feedstuffs, or fertilizers. Care should be taken, also, to avoid cross-contamination of pesticides. Unused insecticides should be kept in the original container and stored in places inaccessible to children, irresponsible persons, or animals. All insecticides should be stored under lock and key.

Procedures for applicators of insecticides--Airplane pilots who are to apply insecticides should not assist in mixing or loading operations. Persons making ground application of organophosphorus insecticides or loading

aircraft with them should always be accompanied by at least one other person in the field.

Information on Poison Control Centers--A publication entitled "Directory of Poison Control Centers" is available upon request from Bureau of Chemical Hazards, Consumer Products Safety Commission, 5401 Westbard Avenue, Bethesda, Md 20016. It lists facilities in each State that provide to the medical profession, on a 24-hour basis, information concerning the prevention and treatment of accidents involving exposure to poisonous and potentially poisonous substances. The telephone directory may also list Poison Control Centers for the local area.

Misapplication or drift on plants, warmblooded animals, and other nontarget areas--Spraying or dusting should be done under conditions and in a manner to avoid direct application or drift to adjacent fields where animals are pastured, where food or feed crops are being grown, or to residential areas, canals, streams, waterways, or highways. Usually there is less drift from sprays than from dusts and from ground applications than from aerial applications. Injury due to misapplication or drift may be determined as the responsibility of the applicator.

Residues in plants or soils--In the development of new insecticides, the possibility of deleterious residues remaining in cottonseed and seed products must be thoroughly investigated. (For more information concerning residues on cotton, see "Restrictions on Use of Insecticides on Cotton, p. 18).

Excessive insecticide residues in the soil may affect germination, rate of growth, and flavor of crops. Concentration of the residue is influenced by the insecticide, the formulation used, amount applied, type of soil, and climatic conditions. Illegal residues have occurred in some root crops and in soybeans grown in rotation with cotton that has been treated with organochlorine insecticides.

Protection of predators and parasites--Predators and parasites play an important role in the control of cotton insects. Most currently available insecticides destroy these beneficial insects as well as harmful ones; therefore, the control program used should take maximum advantage of natural and cultural controls. Insecticides that are selective for the pest species concerned and of minimum detriment to the beneficial species should be used. When regular inspections show that high populations of predators and parasites are present, deferring of insecticide treatments should be considered.

Protection of honey bees--Every year pesticides applied to cotton cause extensive losses of honey bees. Much of this damage is needless and can be averted without reduced control of injurious pests, if proper precautions are taken. Bees are beneficial to cotton, and many cottongrowers as well as their neighbors grow legumes and other crops that require pollination. For the benefit of the beekeeper, the cottongrower, and agriculture in general, every effort should be made to protect pollinating insects.

Bee losses can be reduced if the following general precautions are taken:

1. If a pesticide must be used, choose the one least hazardous to bees that will control the harmful pests.
2. If a hazardous material must be used, apply it when bees are not visiting the field.
3. Use sprays instead of dusts. Application with ground equipment is less hazardous to bees than application by airplane.

4. Avoid drift of pesticide into the apiary or onto adjacent crops in bloom.

5. Reduce the number of applications to an absolute minimum.

6. Advise the beekeeper to locate the apiary out of the usual drift path of the pesticide from the field.

7. Give the beekeeper advance notice if a hazardous material must be used, so he may move or otherwise protect the bees.

8. Remind the beekeeper that confining the bees during and after a single application may prevent or reduce damage, and that colonies can be confined under wet burlap tarpaulins up to 2 days. Confinement is not practical if repeated applications are to be made.

The following grouping shows the relative toxicity to honey bees of insecticides used for control of cotton insects:

Group 1	Group 2	Group 3
Materials highly toxic to bees exposed to direct treatment or residues	Materials toxic to bees when visiting field at time of application	Materials relatively low in toxicity to bees
aldicarb	carbophenothion	*Bacillus thuringiensis*
azinphosmethyl	demeton	chlorbenzilate
carbaryl	disulfoton	chlordimeform
chlorpyrifos	endosulfan	dicofol
diazinon	endrin	ethion
dicrotophos	methomyl (spray)	sulfur
dimethoate	phorate	toxaphene
EPN	trichlorfon (dust)	trichlorfon
malathion		
methamidophos		
methidathion		
methomyl (dust)		
methyl parathion		
monocrotophos		
naled		
parathion		
phosphamidon		

Protection of fish and wildlife--Recommended precautions must be followed to reduce hazards to fish and wildlife when using insecticides for control of cotton insects. It is especially important to avoid direct application or drift to ponds, streams, standing water, and weedy areas.

Wherever possible, cottonfields should be located away from ponds. Runoff from treated fields should be diverted from fish ponds. Where drift may create a problem, sprays are preferred to dusts and ground applications to aerial applications. Do not discard pesticides or clean pesticide application equipment in or near streams or ponds.

Additional safeguards--Equipment that has been used for mixing and applying 2,4-D and other weedkillers should never be used for mixing and applying insecticides to cotton because of the danger of crop injury resulting from contamination of equipment.

REGISTRATIONS OF INSECTICIDES AND MITICIDES

Before a pesticide may be legally shipped in interstate commerce, it must be registered under the Federal Environment Pesticide Control Act of 1972, administered by the Environmental Protection Agency. Scientific data are required to establish that the pesticide, when used as directed on the label, will control the target pest and will not cause adverse effects to man and his surroundings. The criteria for registration are strict and subject to constant review as new information is developed. Many States have similar registration regulations. Under the new law the Administrator of EPA is given the authority to proceed against persons or individuals who engage in misusing pesticides by applying them in a manner "inconsistent with their labeling." In addition, the Administrator may place pesticides in a "restricted use" category, thus subjecting them to controls in distribution and ultimately requiring their use only by trained applicators.

Cottonseed is classified as a food product. The undelinted seed as it comes from the gin is the "raw agricultural commodity."

Where pesticide-use patterns will result in residues of the original material or of toxic metabolites on or in cottonseed or its byproducts, permissible amounts, or tolerances, must be established. The establishment of residue tolerances in raw agricultural commodities is the responsibility of the Environmental Protection Agency. A registration will not be granted until a permissible level of residue has been granted.

Finite tolerances or exemption from tolerances are required for all pesticides registered for use on cotton.

RESTRICTIONS ON USE OF INSECTICIDES ON COTTON

Any regulations established by the Federal or State Governments will take precedence over those given in this report.

Workers entering cottonfields within 2 days after treatment with endrin or with methyl parathion should wear clean, tightly woven protective clothing.

Do not repeat applications of dimethoate within 14 days of each other.

Do not apply disulfoton to cotton more than twice per season or repeat application within 21 days of each other.

Do not repeat applications of monocrotophos within 5 days of each other.

Do not apply chlorbenzilate, endosulfan, ethion, or phorate after bolls begin to open. Dosages of toxaphene in excess of 4 pounds per acre per application should not be applied to cotton after bolls open.

Do not graze livestock in cottonfields treated with insecticides, except those for which no restrictions are shown on the labels.

Unused cottonseed intended for planting that has been treated with any insecticide should not be used for food or feed. Treated seed must bear a statement on the label indicating that the seed has been treated with the chemical and should be used for planting only.

The following insecticides have a reentry time after application of at least the interval indicated:

1 day--azinphosmethyl, EPN, ethion and phosphamidon
2 days--carbophenothion, demeton, dicrotophos, endrin, methyl parathion, monocrotophos, and parathion

The minimum number of days that should elapse between the time of the last insecticidal application and harvest for certain insecticides is as follows:

Hand harvest--
- 2 days--azinphosmethyl in ultra-low-volume applications
- 4 days--naled
- 5 days--endrin
- 7 days--methyl parathion, parathion

Hand or mechanical harvest--
- 1 day--azinphosmethyl
- 3 days--EPN
- 7 days--trichlorfon
- 14 days--diazinon, dimethoate, dicofol, chlorpyrifos, acephate
- 15 days--methomyl
- 21 days--monocrotophos, demeton, chlordimeform
- 28 days--disulfoton, phorate
- 30 days--dicrotophos, phosphamidon
- 60 days--methidathion

Tolerances (parts per million) established for various insecticides recommended for cotton insect control in or on cottonseed are as follows: acephate, 0.5; aldicarb, 0.1; azinphosmethyl, 0.5; carbaryl, 5; carbophenothion, 0.2; chlorobenzilate, 0.5; chlorpyrifos, 0.5; demeton, 0.75; diazinon, 0.2; dicrotophos, 0.05; dicofol, 0.1; dimethoate, 0.1; disulfoton, 0.75; endosulfan, 1; endrin, 0; EPN, 0.5; ethion, 0.5; methamidophos, 0.1; methidathion, 0.2; malathion, 2; methyl parathion, 0.75; methomyl, 0.1; monocrotophos, 0.1; naled, 0.5; parathion, 0.75; phorate, 0.05; phosphamidon, 0.1; toxaphene, 5; and trichlorfon, 0.1. *Bacillus thuringiensis* is exempt from the requirements of a tolerance, and sulfur is a material not requiring a tolerance.

Some States have special restrictions on the use of certain insecticides. Check your State and local regulations.

APPLICATION OF INSECTICIDES AND MITICIDES

Most insecticides and miticides commonly used for control of cotton pests may be readily formulated into either sprays or dusts. Stable formulations of some materials are very difficult to make. Research on formulations continually provides more satisfactory material with greater stability.

Dusts--Most organic insecticides and miticides formulated in dusts with talc, clay, calcium carbonate, phyrophyllite, diatomaceous earth, or sulfur as the carrier give good control of cotton insects and spider mites. The value of formulations with proper dusting characteristics is to be emphasized. Erratic results and poor control are sometimes caused by inferior formulations, although frequently poor results caused by improper application or timing are blamed on formulations. Some dusts containing high percentages of sulfur have undesirable dusting properties and may present a fire hazard.

Sprays--The term "low volume" is used for the application of concentrated insecticides when the total volume of spray applied is more than one-half but less than 10 gallons per acre. The term "ultra-low volume" is used for the application of concentrated or technical insecticides when the total volume of spray liquid applied is one-half gallon or less per acre.

Control of cotton insects and spider mites has been highly successful with properly formulated sprays applied at rates ranging from 1 to 15 gallons per acre. Most of the organic insecticide sprays used on cotton are made from

emulsifiable concentrates. It is recommended that all insecticide formulators show conspicuously on the label the pounds of actual toxicant per gallon in emulsifiable concentrates. The pounds of toxicants specified should be consistent with the required label declaration of active ingredients. Occasional foliage injury has resulted from poorly formulated concentrates or when the spray was improperly applied. Emulsifiers and solvents should be tested for phytotoxicity before they are used in formulations. Phytotoxicity of emulsions may be aggravated by high temperatures, high concentrations, drying winds, and highly alkaline water. Diluted sprays should be applied immediately after mixing and should not be held for later use. Wettable powders of some insecticides are applied to cottonseed in a slurry before planting for control of certain insects.

Ultra-low volume aerial applications of azinphosmethyl, endosulfan, malathion, and methyl parathion are approved for control of certain insects. A mixture of malathion plus methyl parathion is approved for boll weevil and bollworm control in the boll-weevil-infested States. Some progress has been made in applying other compounds in this manner and in developing ground equipment for their application. Results of limited research indicate that some materials perform differently when applied as low volume technical materials or as emulsifiable concentrates than when they are applied as emulsions. Because performance cannot be predicted, each insecticide applied in this manner must be tested thoroughly against various cotton pests. Hazards and residues from such applications must be considered. Expanded research is needed to develop this method of applying insecticides to control cotton insects.

The addition of blackstrap molasses at 1/2 to 2 gallons per acre to insecticidal sprays has improved bollworm control. Molasses increases palatability of spray residues to bollworm larvae and extends the residual effectiveness of certain insecticides. Other benefits include increased kill of bollworm moths and a probable reduction in drift because of increased droplet weight and reduced evaporation.

Granules, fertilizer-insecticide mixtures and seed treatments--Granular formulations of insecticides and mixtures of insecticides and fertilizers are used for control of some soil insects. They are being used for whitefringed beetle and wireworm control in some areas. Granular formulations of some systemic insecticides are being used in some areas against certain foliage-feeding pests. Systemic insecticides are sometimes applied as dusts or liquids to cottonseed before planting for early-season insect control. Such treatments sometimes adversely affect stands and seedling vigor. Emulsifiable formulations of some systemic insecticides are sprayed in the seed furrow at planting for control of certain early-season insects.

Mixtures of two or more insecticides--Where more than one insect or spider mite is involved in a control program, insecticides are frequently combined to give control of the species involved. Bollworm, cotton aphid, and spider mite buildup frequently follows application of some insecticides, and for this reason suitable insecticides or miticides are added to some formulations.

Where an outbreak of aphids or spider mites is involved, a recommended organophosphorus insecticide may be used alone or may be combined in a boll weevil-bollworm formulation.

Emulsifiable concentrates of two or more insecticides may be formulated into the recommended sprays in the field. When this is done, however, the

quantity of solvent is increased which may in turn increase the phytotoxicity hazard and toxicity to man and animals.

Mixtures containing less than recommended dosages of each of several insecticides have frequently been unsatisfactory and are not recommended.

Applications

Insecticides may be applied to cotton with either ground or aerial equipment. Generally sprays and dusts are equally effective. Regardless of equipment chosen, effective control is obtained only when applications give thorough coverage and are properly timed. Improperly timed or unnecessary applications may result in a pest complex that can cause greater damage to the cotton crop than the original target insect.

Ground application--High-clearance rigs usually make efficient application possible in rank cotton with little mechanical injury to plants. Ground machines should be calibrated to apply the proper dosages for the speeds at which they will be operated.

For dust applications the nozzles should be adjusted to approximately 10 inches above the plants, with one nozzle over each row. Dusts are usually applied at 10 to 20 pounds to the acre except in the Far West, where heavier dosages are required. Results of research in Arkansas show that the total volume can be reduced to as little as 2 pounds of dust concentrate per acre with no loss in control if the amount of needed active ingredient is applied.

For spraying seedling cotton under conditions of straight and uniform row spacing, use of one nozzle per row is suggested. As the cotton grows, the number of nozzles should be increased to two or in rank growth to as many as five or six in some areas. Nozzles without drops spaced 20 inches apart on the boom are used in some areas.

The nozzles should be adjusted to approximately 10 inches above the plants and be capable of delivering from 1 to 15 gallons per acre.

Emulsifiable concentrates should be diluted immediately before use. Some type of agitation, generally the bypass flow, is necessary during the spray operation to insure a uniform mixture.

As a safety measure, the spray boom should be located behind the operator.

Aerial application--In aerial application of sprays with fixed-wing aircraft, the plane should be equipped with standard nozzles or rotary atomizing devices that will deliver most of the insecticide in droplets within the range of 100 to 300 micrometers. The aircraft should be flown at a height of 5 feet above the crop for most effective insecticide placement and minimal drift.

Emulsifiable concentrates should be mixed with water immediately before use and delivered in 1 to 10 gallons per acre on a maximum swath width of 40 feet. Ultra-low-volume concentrates should be applied at up to one-half gallon per acre on a swath width of 35 to 75 feet depending on weather and other conditions. Dust applications should be made on a 40-feet maximum swath width. When insect populations are extremely heavy, it may be advantageous to narrow the swath width.

A method of flagging or marking the swaths should be used to insure proper distribution of both sprays and dusts.

Timing of applications--Correct timing is essential for satisfactory control of cotton insects. Consideration must be given to the overall populations and stages of both beneficial and harmful insects rather than to

those of a single insect. The stage of growth of the cotton plant and expected yield are important. Since the use of insecticides often induces outbreaks of aphids, bollworms, spider mites, and other pests, insecticides should be applied only when and where needed.

Early-season applications should be made to control beet armyworm, cutworms, darkling ground beetles, grasshoppers, or other insects which threaten to reduce a stand. Recommendations for early-season applications to control aphids, the boll weevil, the cotton fleahopper, plant bugs, and thrips vary greatly from State to State. Differences in infestations of these insects, as well as many other production factors, make it inadvisable to attempt to standardize recommendations for early-season control.

It is generally recommended that suitable insecticides should be applied to cotton during its maximum period of fruiting and maturing of the crop, if infestations threaten to reduce the yield, affect quality, or delay maturity. Recommendations for insecticide treatments are similar throughout the Cotton Belt, but certain details differ from State to State, and often within a State. The appropriate State Guide for Controlling Cotton Insects should be followed.

Effect of Insecticides on Cotton Plants

Many insecticides affect cotton plants physiologically. The effects may result in delayed or advanced crop maturity with or without accompanying yield loss. Several organochlorine insecticides often cause earlier plant maturity which is a physiological response by the cotton plant.

Many organophosphorus compounds and the carbamate, aldicarb, used as seed or soil treatments have an effect on cotton plants expressed in more vigorous vegetative growth early in the season, resulting in taller plants and larger leaves which can be related to physiological responses. Results have ranged from increased yield and early maturity to reductions in yield and delayed maturity at various locations in the Cotton Belt. Use of organophosphorus and carbamate insecticides at planting has often resulted in delayed plant emergence and poor stands.

Reductions in yield and delays in crop maturity have resulted when early-season foliar application schedules of several organophosphorus compounds have been used. However, more work has been done with methyl parathion and its adverse effects are clearly documented under field conditions. Use of methyl parathion at rates greater than 0.5 pound per acre may result in reduced fruit retention. While plants usually compensate for such fruit loss through production of added fruiting points, the result is delayed crop maturity and in some cases reduced yield. The most severe adverse effects of methyl parathion occur from frequent early-season applications. When methyl parathion is used only as needed, delayed maturity or yield loss does not occur.

Results with carbaryl in California suggest similar reductions in fruit retention without compensating fruiting to offset fruit loss.

Certain solvents and additives may enhance the adverse effects of insecticides or may cause physiological effects of their own.

Effects of several insecticides on growth and fruiting of plants are not consistent from one location to another and from year to year at any particular location. Adverse effects appear to be more common in some areas. Growers and insect control advisers should be aware of the potential adverse

effects of insecticides on crop production. Insecticide use should be based on expected benefits from insect control weighed against possible losses in yield or delay in maturity if it is not used. Researchers should make a greater effort to distinguish between growth and fruiting response of plants caused by insecticides or resulting from control of insects obtained with them.

Determining the Need for Insecticide and Miticide Applications

The determination of pest population levels is fundamental in carrying out a sound cotton insect control program. Entomologists should recognize this basic principle and accept the professional obligation for implementing it. Need for control measures should be based on insect infestation counts.

Insecticides or miticides are recommended for the control of injurious insect and spider mite pests of cotton when their populations reach the level that economic losses will result if they are not controlled. This can be the result of immediate loss of the fruiting forms (squares and bolls) or damage to the plant in such manner that fruiting will be delayed to the extent that a full crop cannot be made during the normal growing season. In areas subject to summer droughts or where the growing season is short, any insect injury causing damage to the extent that fruiting is delayed or early fruit is lost can result in reducing yields. The control of even a light infestation of injurious insects early in the season under these conditions may be important. In much of the Cotton Belt, however, the cotton plant usually is able to overcome early plant damage and early loss of fruit with little or no reduction in yield. In these areas, the need for protecting early fruit and for hastening maturing is minimized.

Some farmers have learned to recognize certain harmful and beneficial insects and certain insect diseases. They can determine by field inspections when an insecticide is needed and by referring to the State Guide can select the proper one to use. Other farmers prefer to employ persons who are specially trained to do the job for them.

Many growers employ specially trained personnel, sometimes referred to as checkers or scouts, to make insect population counts and infestation records in cottonfields. The majority of the scouts are college students or former college students with some entomological background who have been given special training by the extension entomologist or by county agents. The experience of most farmers who have employed them is that money spent for this purpose is a sound investment. The saving of one insecticide application during the year when infestation counts show that it is not needed, or the timely application of one that is needed, usually more than pays the entire cost of the service for the season.

Two types of use of persons specially trained to make insect population counts and infestation records in cottonfields developed. In one, the farmer hires the person to make the records and to submit them to him. The farmer then determines the need for insecticides, selects those to be used from the State Guide for Controlling Cotton Insects, and either applies them with his own equipment or arranges with a custom applicator to do it for him.

In the other type of use the farmer contracts with a consulting entomologist for the complete job of insect control. The consultant may have several individuals making population counts and infestation records for him. His experience enables him to use the records to determine the need for the

insecticide. He makes the selection from the State Guide and either arranges directly for its application or leaves this to the discretion of the owner or manager, depending on the terms of the contract.

Both types of such trained persons have proved highly satisfactory to growers using them, and their use is almost certain to increase. With increased emphasis on reduction in cost of producing cotton and on decreased use of insecticides to avoid residues and other hazards, the precise knowledge of insect conditions and the wise use of insecticides are essential. The employment of trained persons usually is the best way to assure that the job will be properly done.

A pest management program funded by the U.S. Department of Agriculture was initiated in 1972, continued in 1973, and completed in 1974 to encourage cotton producers to use cultural and biological pest control measures in combination with insecticides as needed to protect their crops from damage by insects. The on-farm cotton pest management program was carried out by the Cooperative State Extension Services and Animal and Plant Health Inspection Service in cooperation with the State Departments of Agriculture, Experiment Stations, cotton producers, and other industry leaders. USDA's Animal and Plant Health Inspection Service and Extension Service were responsible for the program on the national level. In 1975 and 1976, some Federal funds under formula were provided to the Cooperative Extension Services in cotton producing States to develop pest management programs. It is hoped that the program will be adopted by growers in the future as an important production practice.

RESISTANCE TO INSECTICIDES AND MITICIDES

Resistance to insecticides and miticides is the ability in insect and spider mite strains to withstand exposure to dosages that exceed that of a normal susceptible population--such ability being inherited by subsequent generations of the strain.

Resistance of cotton pests to insecticides has developed rapidly in recent years. Since 1947, when organic chemicals began to have wide usage in cotton, 25 species of insects and spider mites that attack the crop are known to have developed resistance, and several other species are strongly suspected of having developed resistance. One or more of these resistant species occur in localized areas in most cotton-producing States from California to North Carolina. Most of the pests are resistant to the organochlorine insecticides but four species of mites and the beet armyworm, bandedwing whitefly, bollworm, and tobacco budworm are known to be resistant to the organophosphorus compounds.

The following is a tabulation of the pests known to be resistant to individual insecticides in one or more areas of the States listed:

Pest	Insecticides	States
Bandedwing whitefly	methyl parathion	Arkansas, Louisiana, Tennessee
Beet armyworm	organochlorine compounds	Arizona, Arkansas, California, Mississippi

Pest	Insecticides	States
Beet armyworm	methyl parathion	Alabama
Boll weevil	organochlorine compounds	Alabama, Arkansas, Georgia, Louisiana, Mississippi, North Carolina, Oklahoma, South Carolina, Tennessee, Texas
Bollworm	DDT	Alabama, Arkansas, Arizona, California, Georgia, Louisiana, Mississippi, Missouri, Oklahoma, North Carolina, Tennessee, Texas
	endrin	Arkansas, Louisiana, Mississippi, Oklahoma, Tennessee, Texas, California
	carbaryl	Arizona, Louisiana, Oklahoma, Texas
	methyl parathion	Arkansas, Mississippi, Oklahoma
	TDE	Texas
	toxaphene plus DDT	do.
	strobane plus DDT	do.
	methomyl	Louisiana
Cabbage looper	DDT	Arizona, Georgia, Tennessee, Texas
	organochlorine compounds	Alabama, Arkansas, California, Louisiana, Mississippi, Oklahoma
	endrin and toxaphene	Arizona
	organophosphorus compounds	Arkansas, Louisiana, Mississippi
Cotton aphid	benzene hexachloride	Arkansas, Alabama, Georgia, Louisiana Mississippi, Tennessee

Pest	Insecticides	States
Cotton fleahopper	organochlorine compounds	Texas
	organophosphorus compounds	do.
Cotton leafperforator	organochlorine compounds	California
	DDT	Arizona
	organophosphorus compounds	California, Arizona
Cotton leafworm	organochlorine compounds	Arkansas, Louisiana, Texas
Lygus bugs, *Lygus hesperus*	do.	California
	trichlorfon and monocrotophos	do.
	malathion	do.
	DDT	Arizona
Pink bollworm	DDT	Durango & Coahuila, Mexico, Texas
Saltmarsh caterpillar	toxaphene, DDT, and endrin	Arizona, California
Southern garden leafhopper	DDT	California
Spider mites:		
Tetranychus turkestani	organophosphorus compounds except phorate seed or soil treatment	Alabama, California
T. cinnabarinus	do.	Alabama, Arizona, California, Texas
T. pacificus	do.	do.
T. urticae	do.	Alabama, Arkansas, California, Louisiana, Mississippi, North Carolina

Pest	Insecticides	States
T. pacificus	dicofol	California
T. urticae	dicofol	do.
Stink bug:		
Euschistus consepersus	organochlorine compounds	do.
Thrips:		
Frankliniella Mixture of species	dieldrin	do.
	endrin	California, Georgia
Frankliniella occidentalis	toxaphene	New Mexico
	organochlorine compounds	Texas
Thrips tabaci	organochlorine compounds	do.
Tobacco budworm	carbaryl	Alabama, Arizona, Arkansas, California, Georgia, Louisiana, Mississippi, North Carolina, Oklahoma, South Carolina, Texas
	DDT	Alabama, Arkansas, Georgia, Louisiana, Mississippi, North Carolina, Texas
	endrin	Alabama, Arizona, Arkansas, California, Georgia, Louisiana, Mississippi, North Carolina, Oklahoma, South Carolina, Texas
	Strobane plus DDT	Arkansas, Texas
	TDE	do.
	toxaphene plus DDT	Arkansas, Louisiana, Mississippi, Texas

Pest	Insecticides	States
Tobacco budworm	methomyl	Arizona, Arkansas, Louisiana, Mississippi
	organophosphorus compounds	Alabama, Arizona, Arkansas, California, Georgia, Louisiana, Mississippi, North Carolina, Oklahoma, South Carolina, Tennessee, Texas

Resistance of cotton pests to recommended insecticides is a serious problem. It emphasizes the importance of using every known means possible to alleviate the difficulty to the extent that control may be maintained. This includes the use of pesticides having different physiological modes of action from those to which resistance has been developed and in the use of cultural practices, especially early stalk destruction, in reducing populations of the boll weevil and the pink bollworm. Every advantage possible of biological control agents should be taken, and where there is a choice, chemicals that are of minimum detriment to beneficial insects should be used.

EFFECT OF ENVIRONMENTAL FACTORS ON INSECTICIDAL CONTROL

Failures to control insects have often been attributed to ineffective insecticides, poor formulations, poor applications, and improper timing. Recently, resistance has been blamed for failures in local areas. Variations in humidity, rainfall, temperature, sunlight, and wind have been shown to influence the effectiveness of an insecticide applied to plants. These variations also influence the development of insect populations and plant growth. Inability of the applicator to maintain a regular application schedule because of excessive rains or high winds often results in loss of control at a critical period.

A combination of an adverse effect on the toxicity of the insecticide and a favorable effect on growth of the plant and insect population may result in failure to obtain control. Conversely, conditions favorable to the insecticide and plants and adverse to the insect population will result in very effective control. Use of fertilizer and supplemental irrigation, although valuable in cotton production programs, may create conditions that make insect control difficult. Also certain insects, in particular the boll weevil, become more difficult to kill with some insecticides as the season progresses. Therefore, one should consider all factors before arriving at a decision as to the specific one responsible for the failure to obtain control.

INSECTICIDES AND MITICIDES RECOMMENDED FOR THE CONTROL OF COTTON PESTS

Organochlorine compounds	Organophosphorus compounds	Others
chlorobenzilate	acephate	aldicarb

Organochlorine compounds	Organophosphorus compounds	Others
dicofol	azinphosmethyl	Bacillus thuringiensis
endosulfan	carbophenothion	carbaryl
endrin	chloryprifos	methomyl
toxaphene	demeton	nuclear polyhedrosis viruses
	diazinon	propargite
	dicrotophos	sulfur
	dimethoate	
	disulfoton	
	EPN	
	ethion	
	malathion	
	methamidophos	
	methidathion	
	methyl parathion	
	monocrotophos	
	naled	
	parathion	
	phorate	
	phosphamidon	
	trichlorfon	

Materials recommended for the control of cotton insects in one or more States are discussed in this section (see Table 1, p. 42). In local areas certain insects have become resistant to one or more of the materials recommended (see "Resistance to Insecticides" for details).

Acephate

Acephate will control the bollworm, tobacco budworm, cabbage looper, cotton aphid, lygus bugs, thrips, spider mites, and whiteflies.

Aldicarb

Aldicarb in granular form applied in the furrow at planting will control thrips, cotton aphids, cotton fleahoppers, leafminers, spider mites, lygus bugs, and overwintered boll weevils feeding on foliage. Side-dress applications when plants begin to square will control leafhoppers, cotton fleahoppers, boll weevils, spider mites, and lygus bugs but may result in an increase in subsequent bollworm and tobacco budworm infestations. Treatments at planting may result in phytotoxicity under some conditions to the extent that stands may be damaged.

Aldicarb applied in-furrow at planting or as a sidedressing must be covered completely with soil. It is toxic to fish, wildlife, and birds. Keep out of any body of water. Do not contaminate water when cleaning equipment or disposing of wastes. Birds and wildlife may be killed if allowed to feed on exposed granules.

Aldicarb is highly toxic to man and animals and should be used with adequate precautions.

Azinphosmethyl

Azinphosmethyl will control the boll weevil, brown cotton leafworm, cotton leafperforator, cotton leafworm, fleahoppers, garden webworm, lygus bugs, pink bollworm, stink bugs, and thrips. Erratic results have been obtained against the cotton aphid and spider mite in some areas. It is ineffective against the beet armyworm and the saltmarsh caterpillar.

Azinphosmethyl is highly toxic to man and animals and should be used with adequate precautions.

Bacillus thuringiensis

Bacillus thuringiensis will control the cabbage looper. In field tests HD-1 and HD-73 strains have shown promise against the bollworm and tobacco budworm.

Carbaryl

Carbaryl will control the boll weevil, bollworm, cotton fleahopper, cotton leafworm, cotton leafperforator, cutworms, darkling beetle, fall armyworm, false celery leaftier, field crickets, garden webworm, grasshoppers, a leaf roller (*Platynota stultana*), lygus bugs, pink bollworm, saltmarsh caterpillar, southern garden leafhopper, stink bugs, and thrips. It does not control the beet armyworm, black fleahoppers, cabbage loopers, false chinchbug, or spider mites. Aphids do not usually buildup following its use but spider mites often do.

Carbophenothion

Carbophenothion will control the cotton aphid, cotton fleahopper, cotton leafperforator, lygus bugs, thrips, and most species of spider mites. It appears to have long residual activity. It is not effective against the bollworm, boll weevil, or cabbage looper and is erratic against saltmarsh caterpillars and stink bugs.

Carbophenothion is highly toxic to man and animals and should be used with adequate precautions.

Chlorpyrifos

Chlorpyrifos will control the bollworm, boll weevil, tobacco budworm and spider mites.

Chlorobenzilate

Chlorobenzilate applied as a foliage spray will control most species of spider mites. Complete foliage coverage is essential for obtaining control.

Demeton

Demeton is both a contact and a systemic insecticide with long residual systemic activity. When applied in a foliage spray, it is effective against most species of aphids and spider mites for 2 to 8 weeks and controls the

southern garden leafhopper and thrips. Demeton does not control the boll weevil, bollworm, cotton leafworm, grasshoppers, or the pink bollworm.

Demeton is highly toxic to man and animals and should be used with adequate precautions.

Diazinon

Diazinon in a spray will control the cotton fleahopper, the cotton leafperforator, lygus bugs, the saltmarsh caterpillar, and thrips.

Dicofol

Dicofol is an acaricide with little insecticidal activity. It will control most species of spider mites. For best results spray should be applied at a minimum of 20 gallons per acre with nozzles directed to give coverage under the leaf. Dicofol sprays applied from airplanes have given erratic results.

Dicrotophos

Dicrotophos in a spray will control the cotton aphid, cotton fleahopper, cotton leafperforator, false chinch bugs, lygus bugs, spider mites, saltmarsh caterpillar, stink bugs, and thrips.

Dicrotophos is highly toxic to man and animals and should be used with adequate precautions.

Dimethoate

Dimethoate in a spray will control the cotton aphid, cotton fleahopper, lygus bugs, and thrips.

Disulfoton

Disulfoton as a seed treatment or in granular or spray form applied in the furrow at planting will control aphids, leafminers, spider mites, and thrips for 4 to 6 weeks after planting. Treatments at planting time may result in phytotoxicity under some conditions to the extent that stands may be damaged and early growth retarded. Phytotoxicity hazards may be greater where preemergence herbicides are used. Phytotoxicity hazards are also greater where certain fungicide combinations are used as planter-box treatments with the seed.

Planting seed should be treated only by custom operators who are able to treat seed adequately and uniformly with suitable precautions against hazard to operators.

Disulfoton is highly toxic to man and animals and should be used with adequate precautions.

Endosulfan

Endosulfan will control the bollworm, the cabbage looper, cotton leaf-perforator, lygus bugs, stink bugs, and thrips.

Endrin

Endrin will control the beet armyworm, boll weevil, bollworm, brown cotton leafworm, cabbage looper, cotton leafperforator, cotton leafworm, cutworms, darkling ground beetles, fall armyworm, false chinch bugs, field crickets, flea beetles, fleahoppers, garden webworm, grasshoppers, greenhouse leaftier, lygus bugs, stink bugs, tobacco budworms, thrips, and yellowstriped armyworm. Endrin used in a seed treatment will protect seed and young seedlings from seed corn maggots, false wireworms, and wireworms. It will not control the pink bollworm or spider mites. Aphids usually do not build up after use of endrin, but spider mites sometimes do. Endrin should not be used for control of cotton insects where soybeans are grown in rotation with cotton.

Endrin is highly toxic to man and animals and should be used with adequate precautions.

EPN

EPN will control the boll weevil and bollworm.

EPN is highly toxic to man and animals and should be used with adequate precautions.

Ethion

Ethion will control the cotton aphid, the cotton leafworm, and most species of spider mites.

Methamidophos

Methamidophos will control the beet armyworm, the boll weevil, bollworm, cabbage looper, cotton aphid, cotton leafperforator, lygus bugs, saltmarsh caterpillar, spider mites, and thrips.

Methamidophos is highly toxic to man and animals and should be used with adequate precautions.

Methidathion

Methidathion will control the bandedwing whitefly, spider mites, the boll weevil, and bollworm. In a schedule of applications for control of the latter species, it may be phytotoxic.

Malathion

Malathion spray will control the boll weevil, cotton aphid, brown cotton leafworm, cotton leafperforator, cotton leafworm, fall armyworm, fleahoppers, garden webworm, grasshoppers, lygus bugs, southern garden leafhopper, thrips, and some species of spider mites. Results against whiteflies have been erratic. It will not control the bollworm and the saltmarsh caterpillar. In some areas 0.5 pounds of malathion at 3-day intervals gave boll weevil control comparable to that obtained at 4- to 5-day intervals with higher dosages. Dust formulations have not been entirely satisfactory in some areas, probably because of instability. Malathion applied by airplane in ultra-low-volume sprays at 0.5 to 1.25 pounds per acre controls the boll weevil.

Methomyl

Methomyl will control the beet armyworm, the bollworm, the cabbage looper, cotton leafperforator, lygus bugs, and the pink bollworm. It may be phytotoxic when repeated applications are used. A safened dust is less phytotoxic than sprays.

Methomyl is highly toxic to man and animals and should be used with adequate precautions.

Methyl parathion

Methyl parathion will control the beet armyworm, boll weevil, cabbage looper, cotton aphid, cotton leafperforator, cotton leafworm, cutworms, fall armyworm, false chinch bugs, fleahoppers, garden webworm, grasshoppers, lygus bugs, southern garden leafhopper, saltmarsh caterpillar, stink bugs, thrips, yellowstriped armyworm, and certain species of spider mites, but it has a short residual toxicity. It is not effective against the bollworm, pink bollworm, and tobacco budworm at dosages recommended for the boll weevil but gives bollworm and tobacco budworm control at 1 pound per acre. For late-season weevil control a dosage of 0.25 pound at 3-day intervals is preferred over higher dosages at longer intervals. Although it is unsatisfactory for control of most species of spider mites, methyl parathion in a boll weevil schedule suppresses them. When it is applied as a dust, only stabilized formulations should be used. An encapsulated formulation of methyl parathion has shown promise against the boll weevil, bollworm, and cabbage looper at 0.5 to 1.0 pound per acre.

Methyl parathion is highly toxic to man and animals and should be used with adequate precautions.

Monocrotophos

Monocrotophos will control the bandedwing whitefly, beet armyworm, boll weevil, bollworm, cabbage looper, cotton aphid, cotton fleahopper, cotton leafperforator, lygus bugs, pink bollworm, some species of spider mites, saltmarsh caterpillar, stink bugs, and thrips. This is a water-soluble formulation, and observations indicate that it may be washed off more readily by rain than an emulsifiable concentrate.

Monocrotophos will kill birds and other wildlife. Keep out of any body of water. Do not apply when weather conditions favor drift from areas being treated.

Monocrotophos is highly toxic to man and animals and should be used with adequate precautions.

Naled

Naled will control the cotton fleahopper, cotton leafperforator, cutworms, grasshoppers, and lygus bugs. It is ineffective against the cabbage looper at 0.5 pound per acre and spider mites at 0.5 to 1 pound per acre.

Parathion

Parathion will control the brown cotton leafworm, most species of aphids,

cabbage looper, cotton leafperforator, cotton leafworm, fleahoppers, lygus bugs, false chinch bugs, saltmarsh caterpillar, serpentine leafminers, southern garden leafhopper, stink bugs, some species of spider mites, and thrips. At dosages of 0.5 to 1.0 pound per acre it controls the boll weevil and the bollworm. It gives very little control of the fall armyworm, pink bollworm, variegated cutworm, or whiteflies.

Parathion is highly toxic to man and animals and should be used with adequate precautions.

Nuclear polyhedrosis viruses

One of these viruses controls the bollworm and tobacco budworm and another one controls the cabbage looper.

Phorate

Phorate as a seed treatment or applied in granular form in the furrow at planting will control aphids, leafminers, spider mites, and thrips for 4 to 6 weeks from planting date. Treatments at planting time may result in phytotoxicity under some conditions to the extent that stands may be damaged and early growth retarded. Phytotoxicity hazards may be greater where preemergence herbicides are used. Phytotoxicity hazards are also greater where certain fungicide combinations are used as planter-box treatments with the seed.

Planting seed should be treated only by custom operators who are able to treat seed adequately and uniformly with suitable precautions against hazard to operators.

Foliar applications of phorate will control spider mites.

Phorate is highly toxic to man and animals and should be used with adequate precautions.

Phosphamidon

Phosphamidon will control the cotton aphid, cotton fleahopper, cotton leafperforator, false chinch bugs, lygus bugs, and other mirids, and thrips.

Phosphamidon is highly toxic to man and animals and should be used with adequate precautions.

Propargite

Propargite will control the Pacific, strawberry, and twospotted spider mites.

Sulfur

Sulfur has been widely used in dust mixtures for control of the cotton fleahopper and certain species of spider mites. When applied alone or in combination with insecticides in formulations containing 40 percent or more of sulfur, it will control the desert and strawberry spider mites and will suppress other species. Precautions should be exercised in applying sulfur to cotton adjacent to cucurbits.

Toxaphene

Toxaphene will control the beet armyworm, boll weevil, bollworms, cotton fleahoppers, cotton leafworm, cotton leafperforator, cutworms, fall armyworm, flea beetles, garden webworm, grasshoppers, lygus bugs, stink bugs, thrips, whitelined sphinx, yellowstriped armyworm, and western yellowstriped armyworm. Toxaphene will not control cabbage loopers, the pink bollworm, or saltmarsh caterpillar.

Trichlorfon

Trichlorfon as a spray will control the beet armyworm, celery leaftier, cotton leafperforator, cutworms, darkling beetles, fall armyworm, field crickets, flea beetles, fleahoppers, garden webworm, a leafroller (*Platynota stultana*), lygus bugs, western yellowstriped armyworm, stink bugs, saltmarsh caterpillar, the southern garden leafhopper, and yellowstriped armyworm.

Trichlorfon has given erratic results against bollworms and cabbage loopers. It was not effective against thrips at 0.5 to 1 pound per acre.

Occasionally trichlorfon has been phytotoxic. It should be applied immediately after it is mixed with water.

COMMON AND CHEMICAL NAMES OF INSECTICIDES USED FOR COTTON INSECT CONTROL

(*Indicates a proprietary name)

Common name	Chemical name	Other designations
acephate	*O*,*S*-dimethyl acetyl= phosphoramidothioate	Chevron Ortho 12,420 *Orthene
aldicarb	2-methyl-2-(methylthio)propion- aldehyde *O*-(methylcarbamoyl)= oxime	Union Carbide 21149; UC 21149; *Temik
azinphosmethyl	*O*,*O*-dimethyl S[(4-oxo-1,2,3- benzotriazin-3(4*H*)-yl)methyl] phosphorodithioate	*Guthion; Bayer 17147
carbaryl	1-napthyl methylcarbamate	*Sevin; Union Carbide 7744
carbophenothion	*S*-[[(*p*-chlorophenyl)thio]methyl] *O*,*O*-diethyl phosphorodithioate	*Trithion; Stauffer R-1303
chlorobenzilate	ethyl 4,4'-dichlorobenzilate	Geigy 338; G-23992
chlorpyrifos	*O*-*O*-diethyl-*O*(3,5,6-trichloro- 2-pyridyl) phosphorothioate	Dowco 179; *Dursban *Lorsban
demeton	*O*,*O*-diethyl *O*-[2-(ethylthio)= ethyl]phosphorothioate and *O*,*O*- diethyl *S*-[2-(ehtylthio)ethyl] phosphorothioate	*Systox; mercaptophos

Common name	Chemical name	Other designations
diazinon	O,O-diethyl O-(2-isopropyl-6-methyl-4-pyrimidinyl) phosphorodithioate	G-24480; *Spectracide
dicofol	1,1-bis(p-chlorophenyl)-2,2,2-trichloroethanol	*Kelthane; Rohm and Haas FW-293
dicrotophos	dimethyl phosphate ester with (E)-3-hydroxy-N,N-dimethyl=crotonamide	*Bidrin; Shell SD-3562
dimethoate	O,O-dimethyl S-(methylcarbamoyl=methyl) phosphorodithioate	American Cyanamid 12880; *Rogor; *Cygon; *De-fend
disulfoton	O,O-diethyl S-[2-(ethylthio)=ethyl] phosphorodithioate	*Di-Syston; thiodemeton; Bay 19639
endosulfan	6,7,8,9,10,10-hexachloro-1,5,5a,6,9,9a-hexahydro-6,9-methano-2,4,3,-benzodioxathiepin 3-oxide	*Thiodan; Niagara 5462
endrin	1,2,3,4,10,10-hexachloro-6,7-epoxy-1,4,4a,5,6,7,8,8a-octahydro-1,4-endo-endo-5,8-dimethanonaphthalene	Compound 269
EPN	O-ethyl O-(p-nitrophenyl) phenyl=phosphonothioate	EPN 300
ethion	O,O,O',O'-tetraethyl S,S'-methyl=ene bis(phosphorodithioate)	*Nialate; *Niagara 1240
malathion	diethyl mercaptosuccinate S-ester with O,O-dimethyl phosphorodithioate	Compound 4049
methamidophos	O,S-dimethyl phosphoramidothio=ate	*Monitor; Bay 71628
methidathion	O,O-dimethyl phosphorodithioate S-ester with 4-(mercaptomethyl)-2-methoxy-Δ^2-1,3,4-thiadiazo=lin-5-one	*Supracide; *Ciba-Geigy GS-13005; Fisons NC-2964; *Ultracide
methomyl	S-methyl N-[(methylcarbamoyl)=oxy]thioacetimidate	*DuPONT Insecticide 1179 *Lannate; *Nudrin; *Rivelate

Common name	Chemical name	Other designations
methyl parathion	O,O-dimethyl O-(p-nitrophenyl) phosphorothioate	*Metacide; *Wofatox
monocrotophos	dimethyl phosphate ester with (E)-3-hydroxy-N,-methylcrotonamide	*Azodrin; Shell SD-9129
naled	1,2-dibromo-2,2-dichloroethyl dimethyl phosphate	*Dibrom; Chevron RE-4355
parathion	O,O-diethyl O-(p-nitrophenyl) phosphorothioate	E-605; Compound 3422; *Thiophos; *Niran
phorate	O,O-diethyl S-[ethylthio)methyl] phosphorodithioate	*Thimet; American Cyanamid 3911
phosphamidon	2-chloro-2-diethylcarbamoyl-1-methylvinyl dimethyl phosphate	*Dimecron; OR-1191
propargite	2-(p-tert-butylphenoxy)cyclohexyl 2-propynyl sulfite	Uniroyal D014; *Comite; *Omite
sulfur	sulfur	
toxaphene	chlorinated camphene containing 67% to 69% chlorine	Compound 3956
trichlorfon	dimethyl (2,2,2-trichloro-1-hydroxyethyl)phosphonate	*Dipterex; *Dylox; Bayer L 13/59

INSECTICIDES AND MITICIDES SHOWING PROMISE IN FIELD TESTS

Organophosphorus compounds	Others	
Bay NTN 9306	Carbofuran	NRDC 149
CGA-15324	CM-UTH 1424	NRDC 160
fenitrothion	diflubenzuron	NRDC 161
Rohm & Haas 218	NRDC 143	SD 43775
	NRDC 148	UC 21865
		thiofanox

Materials that have shown promise in the testing programs of the State Agricultural Experiment Stations and the U.S. Department of Agriculture are indicated below. These materials are not recommended for grower use but they are recommended to research workers for further testing and study.

Bay NTN 9306 (*Bolstar) [O-ethyl O-[4-(methylthio)phenyl] S-propyl phosphorodithioate]
In 1973, 1974, 1975, and 1976 this compound in a spray showed promise against the bollworm complex at 0.75 to 1.5 pounds per acre.

The toxicity of this compound is not fully known, but <u>extreme caution</u> should be observed in its use.

<u>Carbofuran (*Furadan)</u> (2,3-dihydro-2,2-dimethyl-7-benzofuranyl methylcarbamate)

Carbofuran applied in the seed furrow at planting in a granular formulation at 0.5 to 1.0 pound per acre showed promise against thrips. In field tests from 1964 through 1974, carbofuran applied as a foliar spray has showed promise against the bollworm, boll weevil, cotton aphid, cotton leafperforator, lygus bugs, bandedwing whitefly, and thrips at rates of 0.5 to 1.0 pound per acre.

The toxicity of this compound is not fully known, but <u>extreme caution</u> should be observed in its use.

<u>CIBA-Geigy CGA-15324</u> [(<u>O</u>-4-bromo-2-chlorophenyl) <u>O</u>-ethyl <u>S</u>-propyl phosphoro=thioate]

In field tests in 1975 and 1976, this compound in a spray showed promise against the bollworm complex at 0.5 to 2.0 pounds per acre. In 1976 it showed promise against the boll weevil at 0.75 to 1.0 pound per acre.

The toxicity of this compound is not fully known, but <u>extreme caution</u> should be observed in its use.

<u>Celamerck CM-UTH 1426</u> (1-3-bis(3-chlorophenyl)-2-(trichloromethyl) imidazolidine)

In field tests in 1976, this compound in a spray showed promise against the boll weevil, bollworm, and tobacco budworm at 0.5 to 1.0 pound per acre.

The toxicity of this compound is not fully known, but <u>extreme caution</u> should be observed in its use.

<u>Diflubenzuron (*Dimilin)</u> [1-(<u>p</u>-chlorophenyl)-3-(2,6-difluorobenzoyl)urea]

In small field tests in 1974 this compound in an invert sugar-molasses sprayable bait at 0.25 and 0.5 pound per acre reduced hatch of eggs from overwintered boll weevil females by 98 percent. In small field tests in 1975, it showed promise against the boll weevil at 0.0625 to 0.5 pound per acre. In a large field test conducted in an isolated area, this compound applied in a cottonseed oil spray at 0.25 pound per acre gave more than 99 percent suppression of the boll weevil population throughout the season. In 1976 this compound suppressed boll weevil populations in a flowable formulation at 0.06 pound to 0.125 pound and in a wettable powder formulation at 0.03 to 0.125 pound per acre.

The toxicity of this compound is not fully known, but <u>extreme caution</u> should be observed in its use.

<u>Fenitrothion (*Sumithion)</u> [<u>O</u>,<u>O</u>-dimethyl <u>O</u>-(4-nitro-<u>m</u>-tolyl)phosphorothioate]

In 1976 fenitrothion in a spray showed promise against the boll weevil, bollworm, and tobacco budworm at 1.0 pound per acre. Results obtained with this material as Bay 41831 were previously reported in the Fifteenth and Sixteenth Annual Reports.

The toxicity of this compound is not fully known, but <u>extreme caution</u> should be observed in its use.

<u>NRDC 143</u> [m-phenoxybenzyl <u>cis</u>,<u>trans</u>-(±)-3-(2,2-dichlorovinyl)-2,2-dimethyl=

cyclopropanecarboxylate]

In 1974 and 1975, FMC 33297 in a spray showed promise against the boll weevil, bollworm, tobacco budworm, cotton leafperforator, and pink bollworm at 0.05 to 0.2 pounds per acre. In 1975 it showed promise against lygus bugs at 0.1 pound, thrips and cotton fleahopper at 0.05 pound, and the bandedwing whitefly at 0.075 pound per acre. In 1976 it showed promise against the boll weevil, bollworm, tobacco budworm, pink bollworm, and cotton leafperforator at 0.1 to 0.2 pound per acre.

In 1975, ICI PP557, a similar or the same compound, gave similar results to the extent that it was tested. In 1976 it showed promise against the boll weevil, bollworm, tobacco budworm, pink bollworm and cotton leafperforator at 0.1 to 0.2 pound per acre.

Ordinary precautions are recommended in its use.

NRDC-148 (FMC-45182)[(3-phenoxyphenyl)methyl *cis*-(±)-3-(2,2-dichloroethenyl)-2,2-dimethylcyclopranecarboxylate]

In 1976, FMC-45182 in a spray showed promise against the boll weevil, bollworm, and tobacco budworm at 0.05 to 0.1 pound per acre.

Ordinary precautions are recommended in its use.

NRDC-149 (FMC-30980) (*R*,*S*)-[cyano(3-phenoxyphenyl)methyl] *cis*, *trans*-(±) 3-(2,2-dichloroethynyl)-2,2 dimethylcyclopropanecarboxylate

In 1976, FMC-30980 in a spray showed promise against the boll weevil, bollworm, and tobacco budworm at 0.05 to 0.1 pound per acre.

Ordinary precautions are recommended in its use.

NRDC-160 (FMC-45497) (*R*,*S*)-[cyano(3-phenoxyphenyl)methyl] *cis*-(±)-3-(2,2-dichloroethenyl)-2,2-dimethylcyclopropanecarboxylate

In 1976, FMC-45497 in a spray showed promise against the boll weevil, bollworm, and tobacco budworm at 0.05 to 0.1 pound per acre.

Ordinary precautions are recommended in its use.

NRDC-161 (FMC-45498) (*S*)-[cyano(3-phenoxyphenyl)methyl] *cis*-(+)-3-(2,2-dibromoethenyl)-2,2-dimethylcyclopranecarboxylate)

In 1976, FMC-45498 in a spray showed promise against the boll weevil, bollworm, tobacco budworm, pink bollworm and cotton leafperforator at 0.01 to 0.02 pound per acre.

The toxicity of this compound is not fully known but *extreme caution* should be observed in its use.

Rohm & Haas 218 *O*-(2,4,6-trichlorophenyl) *O*-ethyl, *S* propyl phosphorothioate)

In field tests in 1974 and 1975, this compound showed promise against bollworms and lygus bugs at 0.5 to 1.0 pound per acre. In repeated applications this compound may be phytotoxic.

The toxicity of this compound is not fully known, but *extreme caution* should be observed in its use.

Shell SD-43775 cyano(3-phenoxyphenyl)methyl 4-chloro-alpha-(1-methyl ethyl benzeneacetate)

In field tests in 1975 this material in a spray showed promise against the bollworm, boll weevil, tobacco budworm, cotton leafperforator, thrips, and pink bollworm at 0.05 to 0.2 pound per acre. In 1976 it showed promise

against the boll weevil, bollworm, tobacco budworm, and beet armyworm at 0.1 to 0.2 pound and against whitefly adults at 0.1 pound per acre.

Ordinary precautions are recommended in its use.

UC 21865 2 methyl-2-(methylsulfonyl) propionaldehyide O-(methylcarbamoyl)=oxime

In 1976 UC 21865 as a seed treatment at 0.5 to 1.0 pound per hundredweight showed promise against thrips.

The toxicity of this compound is not fully known, but extreme caution should be observed in its use.

Thiofanox (Dacamox 10G) [3,3-dimethyl-1-1-(methylthio)-2-butanone O-[(methylamino)carbonyl]oxime]

In field tests in 1972, this material in granular form applied in the seed furrow at planting at 0.6 to 1.6 pounds per acre gave control of thrips, cotton aphids, leafminers, and spider mites for 6 weeks and cotton fleahoppers for 9 weeks after planting. In 1973, 1974, and 1976, this material in granular form applied in the seed furrow at planting at 0.3 to 0.9 pound per acre showed promise against thrips. As a seed treatment it was effective against thrips when applied at 0.25 to 1.0 pound per hundredweight of seed.

Thiofanox is highly toxic to man and animals and should be used with adequate precautions.

COTTON INSECTS AND SPIDER MITES AND THEIR CONTROL

The insects and spider mites injurious to cotton and the recommended chemicals and procedures for their control are discussed in this section. Dosage ranges for insecticides recommended in one or more States for the control of cotton pests are shown in table 1. In local areas certain insects have become resistant to one or more of the insecticides recommended for general use. (See "Resistance to Insecticides," pp. 24 to 28 for details.)

Beet armyworm, *Spodoptera exigua* (Hbn.)

The following insecticides will control the beet armyworm in some areas at the indicated dosages of technical material.

Sprays or dusts	Pounds per acre
methamidophos	0.5-1.0
methomyl	0.3-0.5
methyl parathion	1.0-1.5
monocrotophos	0.4-1.0
parathion + methyl parathion	0.5+1.0
trichlorfon	1.0-1.5

In 1974 a bait containing 1.25 or 2.5 percent of methomyl applied at 20 pounds per acre showed promise against beet armyworms.

The beet armyworm often is a pest of seedling cotton, but it also attacks older plants. Squares and blooms may be destroyed, and feeding on the bracts may cause small bolls to shed.

Although beet armyworm has been a pest in the West and Southwest for

many years, it was reported from Louisiana and Mississippi in 1962. Injurious infestations occurred in some localities in Alabama and Georgia in 1963, in Alabama, Arkansas, and Mississippi in 1969, and in South Carolina in 1970. It was a serious pest of cotton in Georgia in 1973 and 1974.

Boll Weevil, *Anthonomus grandis* Boheman

The boll weevil occurs in the cotton-producing area encompassing the eastern two-thirds of Texas and Oklahoma and eastward to the Atlantic Ocean. Since 1960 it has extended its range to west Texas and poses a threat to cotton in New Mexico. A boll weevil found attacking cotton in northwestern Mexico and Arizona poses a threat to cotton production in New Mexico and California. It was found in California for the first time in 1965. Control programs initiated 12 years ago in western Texas are being continued to prevent further spread.

The effectiveness of insecticides approved for boll weevil control will vary not only in different localities but also with the season. The choice of insecticides will be determined by their effectiveness in the particular area where the insect is to be controlled. Dosages of technical material that have controlled the boll weevil in mid-season and late-season in one or more areas are as follows (dosages lower than these are used for early-season control in some areas):

Sprays or dusts	Pounds per acre
acephate	1.0
azinphosmethyl 1/	0.25-0.5
carbaryl	1.0-2.0
EPN	0.5
EPN + methyl parathion	0.25-0.5+0.25-0.5
malathion 1/	0.5-2.0
malathion + methyl parathion 1/	1.0+1.0
methyl parathion 1/	0.25-1.0
monocrotophos	0.6-1.0
parathion	0.5-1.0
toxaphene	2.0-3.0

1/ Azinphosmethyl, malathion, malathion + methyl parathion, and methyl parathion may be applied ultra-low volume as technical material at 0.125-0.25 pound, 0.5 to 1.2 pounds, 1.12-1.50+0.56-0.75 pound and 0.5 to 0.75 pound per acre, respectively.

Aldicarb is effective against overwintered boll weevils when used as in-furrow granule application at planting at 0.6 to 1.0 pound per acre.

When these insecticides are used for boll weevil control, other insect problems have to be considered. Infestations of the cotton aphid, the bollworm, spider mites, and the tobacco budworm may develop when some of these insecticides are used alone.

Spider mites may build up rapidly after the use of toxaphene or with carbaryl. Careful checks should be made at 5- to 7-day intervals. If these pests are found to be increasing, control measures should be started at once. (See sections on "Cotton Aphid" and "Spider Mites," pp. 46 and 53.)

Boll weevil control measures should be taken when definite need is

Table 1.--Recommended dosages of technical material in a dust or emulsion spray for the principal insecticides used for the control of cotton insects[1]

[Pounds per acre]

Insecticide	Boll weevil	Bollworm or tobacco budworm	Cabbage looper	Cotton aphid	Cotton leaf-perforator	Cotton leafworm	Cutworms	Fall armyworm
Acephate	1.0	1.0	--	--	--	--	--	--
Bacillus thuringiensis	--	--	3.6-8X10^9IUs	--	--	--	--	--
aldicarb[2]	0.6-1.0	--	--	0.3-0.5	2.0	--	--	--
azinphosmethyl[3]	0.25-0.5	--	--	0.25-0.5	--	0.25-0.5	--	--
carbaryl	1.0-2.0	1.0-2.0	--	--	--	0.5-1.0	1.5	1.0-2.0
carbophenothion	--	--	--	0.5-1.0	--	--	--	--
chloryprifos	--	0.7-1.0	--	--	--	--	--	--
demeton	--	--	--	0.38	--	--	--	--
dicrotophos	--	--	--	0.1-0.5	--	--	--	--
dimethoate	--	--	--	0.1-0.5	--	--	--	--
disulfoton[4]	--	--	--	0.6-1.0	--	--	--	--
endosulfan	--	1.0	1.0	--	--	--	--	--
endrin	--	0.3-0.6	--	--	--	--	--	--
EPN	0.5	1.0	--	--	--	--	--	--
ethion	--	--	--	0.5	--	--	--	--
malathion[3]	0.5-2.0	--	--	0.5-1.25	--	0.4-1.25	--	--
methamidophos	--	0.5-1.0	0.5-1.0	0.5-1.0	--	--	--	--
methomyl	--	0.45-0.67	--	--	0.45-0.67	--	--	--
methyl parathion[3]	0.25-1.0	1.0-2.0	0.5-1.0	0.25-0.5	--	0.12-0.5	--	0.25-2.0
monocrotophos	0.6-1.0	0.6-1.0	0.6-1.0	--	--	--	--	--
nuclear polyhedorsis viruses	--	[6]0.12-0.25	--	--	--	--	--	--
parathion	0.5-1.0	--	--	0.1-0.38	--	0.12-0.25	--	--
phorate[5]	--	--	--	0.5-1.5	--	--	--	--
phosphamidon	--	--	--	0.18-0.5	--	--	--	--
toxaphene	2.0-3.0	2.0-4.0	--	--	--	2.0-3.0	2.0-4.0	2.0-3.0
trichlorfon	--	--	--	--	--	--	1.5	--

Insecticide	Cotton fleahopper	Garden webworm	Grass- hoppers	Lygus bugs & other mirids	Pink bollworm	Saltmarsh caterpillar	Stink bugs	Thrips
aldicarb 2/	0.6-1.0	--	--	0.6-1.0	--	--	--	0.3-0.5
azinphosmethyl	0.1-0.25	--	--	0.25-0.5	0.5-1.0	--	--	0.08-0.4
carbaryl	0.5-1.5	1.0-2.0	0.5-1.5	0.5-2.5	2.0-2.5	2.0	1.25-2.5	0.35-1.0
diazinon	--	--	--	--	--	1.0	--	--
dicrotophos	0.1-0.4	--	--	0.1-0.25	--	--	--	0.25
dimethoate	0.1-0.4	--	--	0.1-0.5	--	--	--	0.1-0.4
disulfoton 4/	--	--	--	--	--	--	--	0.6-1.0
endosulfan	--	--	--	1.0	--	--	1.0	--
malathion	0.7-1.25	1.0-2.0	1.0-2.0	0.5-2.5	--	--	--	0.4-2.5
methyl parathion 3/	0.12-0.5	0.25-0.5	0.25-0.5	0.125-0.5	--	1.0	0.75-1.5	0.12-0.5
monocrotophos	--	--	--	0.1-0.5	0.6-1.0	--	--	7/ 0.25-1.25
naled	--	--	0.5-0.75	--	--	--	--	--
parathion	0.25-0.5	--	--	--	--	--	0.5-1.0	--
phorate 5/	--	--	--	--	--	--	--	0.5-1.5
phosphamidon	0.18-0.5	--	--	0.18-0.5	--	--	--	0.18-0.5
toxaphene	1.0-4.0	3.0-4.0	2.0-4.0	2.0-4.0	--	--	--	0.18-1.5
trichlorfon	0.25-1.0	--	--	0.5-1.5	--	1.5	1.0-1.5	--

1/ Information on recommended insecticides for the following insects not shown is found on the following pages: Beet armyworm, p. 40; darkling beetles, p. 48; field crickets, p. 59; seed corn maggots, p. 53; whitefringed beetles, p. 57; wireworms, p. 57; yellowstriped and western yellowstriped armyworms, p. 57.

2/ In-furrow granule treatment at planting.

3/ Azinphosmethyl, malathion, and methyl parathion may be applied ultra-low volume as technical material per acre at 0.125-0.25, 0.5-1.2, and 0.5-0.75 pounds per acre, respectively.

4/ In-furrow granule at planting. Seed treatment for cotton aphid and thrips control at 0.25 to 0.5 pound per hundredweight of seed.

5/ In-furrow granule treatment at planting. Seed treatment at 1.3 to 1.5 pounds per hundredweight of planting seed.

6/ 36-72 larval equivalents per acre.

7/ Per hundredweight of planting seed.

established. Experience indicates that mid-season and late-season control programs may require frequent applications. Fields should be inspected weekly until bolls are no longer susceptible to attack by weevils. Where early-season control is required, experience indicates that frequent treatments may also be needed during the period of abundance of overwintered weevils. Insecticide treatments should be based on actual need.

Certain chemical and cultural control procedures may be used during and immediately following cotton harvest to greatly reduce the overwintering boll weevil population. The boll weevil survives the winter as a diapausing adult. Most of the adults must feed on fruiting forms for approximately 10 days to 3 weeks to attain diapause. Very few weevils attain diapause when insecticides are applied for their control before cotton matures. Large numbers of weevils attain diapause soon after the termination of the regular control program and before the food supply is destroyed, either by a killing frost or by chemical and mechanical methods. A proper combination of practices at this time, including applications of organophosphorus insecticides, defoliation, and stalk destruction to prevent the development of diapause by the weevils will reduce overwintering populations by approximately 90 percent.

In the Pilot Boll Weevil Eradication Experiment conducted in south Mississippi and adjoining areas of Louisiana and Alabama in 1971-1973, an effective component in the suppression program was a trap plot of cotton consisting of about 2 percent of the acreage in each field. The trap plot, planted some 2 weeks earlier than the remainder of the field, was planted by the grower. Its purpose was to attract overwintered boll weevils. An in-furrow application of 1 pound of aldicarb per acre was made at planting and a sidedressing of 2 pounds when plants began to square to kill off the weevils. Grandlure used in 100-foot interval bait stations within the trap intensifies attraction of weevils. If aldicarb is not used, a conventional insecticide must be applied at 5-day intervals after the plants in the trap plot begin to square to kill off the overwintered weevils.

Bollworm, *Heliothis zea* (Boddie), and Tobacco Budworm, *H. virescens* (F.)

The bollworm and the tobacco budworm are the common bollworms attacking cotton. Several other species of lepidopterous larvae that cause boll injury, discussed elsewhere in this report, are the fall armyworm, pink bollworm, yellowstriped armyworm, and western yellowstriped armyworm.

The bollworm and tobacco budworm occur throughout the Cotton Belt although injurious infestations of the tobacco budworm usually occur from Texas eastward. The latter species has always been more difficult to control. Beginning in the 1960's the tobacco budworm became extremely difficult to control in Texas and in the 1970's in Louisiana, Arkansas, Mississippi, and South Carolina as well.

Effective control of bollworms depends on the thoroughness and proper timing of insecticide applications. Frequent field inspections to determine the presence of eggs, young larvae, and square damage during the fruiting period are essential. For the most effective control, it is essential that insecticide applications be made when larvae are small.

In the 1960's available insecticides failed to control high populations of tobacco budworms in Texas and Oklahoma. Similar control failures occurred in Arkansas and Louisiana in 1974, in some areas of Alabama, Mississippi, and

South Carolina in 1975, and, thereafter in the remaining cotton producing States east of the Mississippi River, and in Arizona and in the Imperial Valley of California. Failures to control tobacco budworms with available insecticides are expected to increase in the future.

Dosages of technical material that have controlled "bollworms" in one or more areas are as follows:

Sprays or dusts	Pounds per acre
acephate	1.0
carbaryl	1.0-2.0
carbaryl + methyl parathion	2.0-3.0+0.5-1.0
chloryprifos	0.7-1.0
endosulfan	1.0
endosulfan + methyl parathion	0.5-1.5+0.3-1.0
endrin	0.3-0.6
endrin + methyl parathion	0.2-0.5+0.2-0.6
EPN	0.5-1.0
EPN + methyl parathion	0.5-0.7+0.7-1.2
malathion + methyl parathion 1/	1.0+1.0
methamidophos	0.5-1.0
methomyl	0.45-0.67
methyl parathion 2/	1.0-2.0
monocrotophos	0.6-1.0
nuclear polyhedrosis viruses 3/	0.12-0.25
toxaphene	2.0-4.0
toxaphene + methyl parathion	1.0-4.0+0.75-1.5
toxaphene + EPN	1.5-2.0+0.5-0.67

1/ May be applied ultra-low volume at 1-1.5+0.56-0.75 pounds per acre.
2/ May be applied ultra-low volume at 0.5 to 0.75 pounds per acre.
3/ 36-72 larval equipment per acre.

Cabbage Looper, *Trichloplusia ni* (Hubner)

The cabbage looper and related species are pests of cotton in many areas. They are difficult to control with insecticides. The following materials applied at 5-day intervals have given control in one or more areas:

Sprays or dusts	Pounds per acre
Bacillus thuringiensis	$3.6\text{-}8 \times 10^9$ IUs
endosulfan	1.0
methamidophos	0.5-1.0
methyl parathion	0.5-1.0
monocrotophos	0.6-1.0

The cabbage looper is frequently controlled by virus and fungus disease organisms. When diseased loopers are commonly found, chemical control may be delayed or omitted.

Cotton Aphid, *Aphis gossypii* Glover

Heavy infestations of the cotton aphid may occur on cotton after the use of certain insecticides and on seedling cotton and sometimes on older cotton where no insecticides were applied.

Aphid buildup in the boll weevil areas usually can be prevented by any of the following treatments:

1. Endrin at 0.2 to 0.5 pound per acre in every application in a dust or spray.
2. Methyl parathion at 0.25 to 0.5 pound, or malathion at 1 to 2 pounds per acre in a dust or spray in every application.
3. Carbaryl at 1 to 2 pounds per acre in every application in a dust or spray.

When aphid infestations are heavy and rapid kill is needed, any one of the following treatments is usually effective at the dosages of technical material shown as follows:

Sprays or dusts	Pounds per acre
azinphosmethyl	0.25-0.5
carbophenothion	0.5-1.0
dimethoate	0.1-0.5
ethion	0.5
malathion	0.5-1.25
methamidophos	0.5-1.0
methyl parathion	0.25-0.5
parathion (ethyl)	0.1-0.38
phosphamidon	0.18-0.5
Spray only	
demeton	0.38
dicrotophos	0.1-0.5

The following materials are effective when used as seed treatments or as in-furrow granule applications at planting at the indicated dosages of technical material:

	Pounds per acre	Pounds per hundredweight of cottonseed
aldicarb	0.3-0.5	
disulfoton	0.6-1.0	0.25-0.5
phorate	0.5-1.5	1.3-1.5

Cotton Fleahopper, *Pseudatomoscelis seriatus* (Reuter)

The cotton fleahopper frequently attacks cotton in Texas and Oklahoma and, to a lesser extent, eastward and westward during the early fruiting period. It can be controlled with the following insecticides at the indicated dosages of technical materials:

Sprays or dusts	Pounds per acre
azinphosmethyl	0.1-0.25
carbaryl	0.5-1.5
dicrotophos	0.1-0.4
dimethoate	0.1-0.4
malathion	0.7-1.25
methyl parathion	0.12-0.5
parathion	0.25-0.5
phosphamidon	0.18-0.5
toxaphene	1.0-4.0
trichlorfon	0.25-1.0

Aldicarb is effective when used as an in-furrow granule application at planting at 0.6 to 1.0 pound per acre.

The black fleahopper complex, Spanagonicus albofasciatus (Reuter) and Rhinacloa forticornis (Reuter), occurs on cotton in the irrigated West. The former species also occurs in the Mississippi Delta. More information is needed on both of these species to clarify their roles as economic pests of cotton and as predators.

Cotton Leafperforator, Bucculatrix thurberiella Busck

The cotton leafperforator is at times a serious defoliator of cotton in certain areas of southern California and Arizona. It is controlled with methomyl (spray or dust) at 0.45 to 0.67 pound per acre (technical material).

Repeat applications may be necessary. Sprays are more effective than dusts. Avoid use of organophosphorus compounds during early season to protect beneficial insects.

Aldicarb is effective when applied as a sidedressing between first squaring and early bloom at 2.0 pounds per acre.

Cotton Leafworm, Alabama argillacea (Hübner)

The following insecticides will control the cotton leafworm at the indicated dosages of technical material:

Sprays or dusts	Pounds per acre
azinphosmethyl	0.25-0.5
carbaryl	0.5-1.0
malathion	0.4-1.25
methyl parathion	0.12-0.5
parathion	0.12-0.25
toxaphene	2.0-3.0

Cutworms

Several species of cutworms, including the following, may develop in weeds or crops, especially legumes, and then attack adjacent cotton or cotton planted on land previously in weeds or legumes:

Black cutworm, *Agrotis ipsilon* (Hufnagel)
Palesided cutworm, *A. malefida* Guenee
Variegated cutworm, *Peridroma saucia* (Hubner)
Granulate cutworm, *Feltia subterranea* (F.)
Army cutworm, *Euxoa auxilliaria* (Grote)

Recommended control measures include thorough seedbed preparation, elimination of weed host plants, and the use of insecticides. In western areas, irrigation forces the subterranean forms to the surface where they may be treated with insecticides or destroyed by natural factors. If the vegetation in an infested area is plowed under 3 to 6 weeks before the cotton crop is seeded, use of an insecticide may not be needed.

The following insecticides will control one or more species of cutworms at the indicated dosages of technical material:

Sprays or dusts	Pounds per acre
carbaryl	1.5
toxaphene	2.0-4.0
trichlorfon	1.5

Poison baits containing toxaphene at 2 to 4 pounds, carbaryl at 1.5 pounds, and trichlorfon at 1.5 pounds per acre have been satisfactory. Baits are frequently more effective than sprays or dusts against some species of cutworms.

Darkling ground beetles, *Blapstinus* spp. and *Ulus* spp.

Darkling ground beetles, the adults of false wireworms, occasionally affect the stand of young cotton in the western areas. Adults on young plants may be controlled with carbaryl in a bait at 1.5 pounds, or endrin at 0.075 to 0.11 pound per acre.

Fall Armyworm, *Spodoptera frugiperda* (J. E. Smith)

The fall armyworm occasionally occurs in sufficient numbers to damage cotton. The following insecticides will control it at the indicated dosages of technical material:

Sprays or dusts	Pounds per acre
carbaryl	1.0-2.0
methyl parathion	0.25-2.0
toxaphene	2.0-3.0

The results obtained from these materials have varied in different States; therefore, local recommendations should be followed. (Also, see "Bollworm," pp. 44.)

Garden Webworm, *Loxostege rantalis* (Guenee)

The garden webworm may be controlled with the following insecticides at

the dosage indicated:

Sprays or dusts	Pounds per acre
carbaryl	1.0-2.0
malathion	1.0-2.0
methyl parathion	0.25-0.5
toxaphene	3.0-4.0

Grasshoppers

Several species of grasshoppers, including the following, sometimes attack cotton:

American grasshopper, _Schistocerca americana_ (Drury)
Trimerotropis pallidipennis pallidipennis (Burmeister)
Differential grasshopper, _Melanoplus differentialis_ (Thomas)
Lubber grasshopper, _Brachystola magna_ (Girard)
Migratory grasshopper, _M. sanguinipes_ (F.)
Redlegged grasshopper, _M. femurribrum_ (De Geer)
Twostriped grasshopper, _M. bivittatus_ (Say)

The American grasshopper overwinters as an adult and in the spring deposits eggs in the fields. Other species of grasshoppers overwinter as eggs in untilled soil, fence rows, sod waterways, around stumps, and similar locations. The species overwintering in the egg stage can be best controlled with early treatment of hatching beds before the grasshoppers migrate into the fields. Sprays or dusts have largely replaced poison baits, particularly where grasshoppers must be controlled on lush or dense vegetation.

Dosages of technical material suggested to control grasshoppers on cotton come within the following ranges:

Sprays or dusts	Pounds per acre
carbaryl	0.5-1.5
malathion	1.0-2.0
methyl parathion	0.25-0.5
naled	0.5-0.75
toxaphene	2.0-4.0

The lowest dosages are effective against newly hatched to half-grown grasshoppers. The dosages should be increased as the grasshoppers mature or when the material is applied on partly defoliated plants or on plants unpalatable to the insects.

Lygus Bugs and Other Mirids

Several species of lygus bugs and mirids, including those listed below, often are serious pests of cotton. (See cotton fleahopper, table 1.)

A plant bug, _Lygus hesperus_ Knight
Clouded plant bug, _Neurocolpus nubilus_ (Say)
Ragweed plant bug, _Chlamydatus associatus_ (Uhler)

Rapid plant bug, _Adelphocoris rapidus_ (Say)
Superb plant bug, _A. superbus_ (Uhler)
Tarnished plant bug, _Lygus lineolaris_ (Palisot de Beauvois)

The mirids, _Creontiades debilis_ Van Duzee, _Reuteroscopus ornatus_ (Reuter), _R. sulphureus_ (Reuter), and _Paraxentus guttulatus_ (Uhler) also damage cotton. _C. rubrineruis_ (Stal.) infested cotton in the Lower Rio Grande Valley of Texas in 1974, 1975, and 1976.

The insects cause damage to squares, blooms, and small bolls of cotton and constitute a major problem, particularly in the vicinity of alfalfa fields in the irrigated areas of the West.

The following insecticides will control lygus bugs and other mirids at the indicated dosages of technical material:

Sprays or dusts	Pounds per acre
azinphosmethyl	0.25-0.5
carbaryl	0.5-2.5
dicrotophos	0.1-0.25
dimethoate	0.1-0.5
endosulfan	1.0
malathion	0.5-2.5
methyl parathion	0.12-0.5
monocrotophos	0.1-0.5
phosphamidon	0.18-0.5
toxaphene	2.0-4.0
trichlorfon	0.5-1.5

Aldicarb is effective when used as an in-furrow granule application at planting at 0.6 to 1 pound per acre.

Pink Bollworm, _Pectinophora gossypiella_ (Saunders)

The pink bollworm occurs on the North American continent in Texas, California, Nevada, Oklahoma, New Mexico, Arizona, Arkansas, and Louisiana. It occurs in wild cotton in southern Florida. Although it also occurs in most of Mexico, it was found for the first time in 1965 in limited areas of the previously uninfested States of Sonora and Baja California. Quarantine regulations, the application of chemical controls, and cultural control requirements have made it possible to prevent economic damage in most years in the infested areas of the United States and to retard or to prevent its spread to new areas. However, in recent years injurious infestations have occurred in the Imperial and Coachella Valleys of California and in Arizona.

Quarantine requirements--The area presently under regulation in the United States is shown in the map on page 52. Regulations, in general, require that all cotton or other designated articles moved from the regulated area be treated to free them of any living pink bollworms before movement to free areas. All cottonseed must be treated before being shipped from an infested area. Copies of the State and Federal regulations may be obtained from the regulatory agencies of the affected States or from the Plant Protection Program field offices.

Cultural Control--Approved cultural practices, effective and economical means of controlling the pink bollworm when properly carried out, greatly

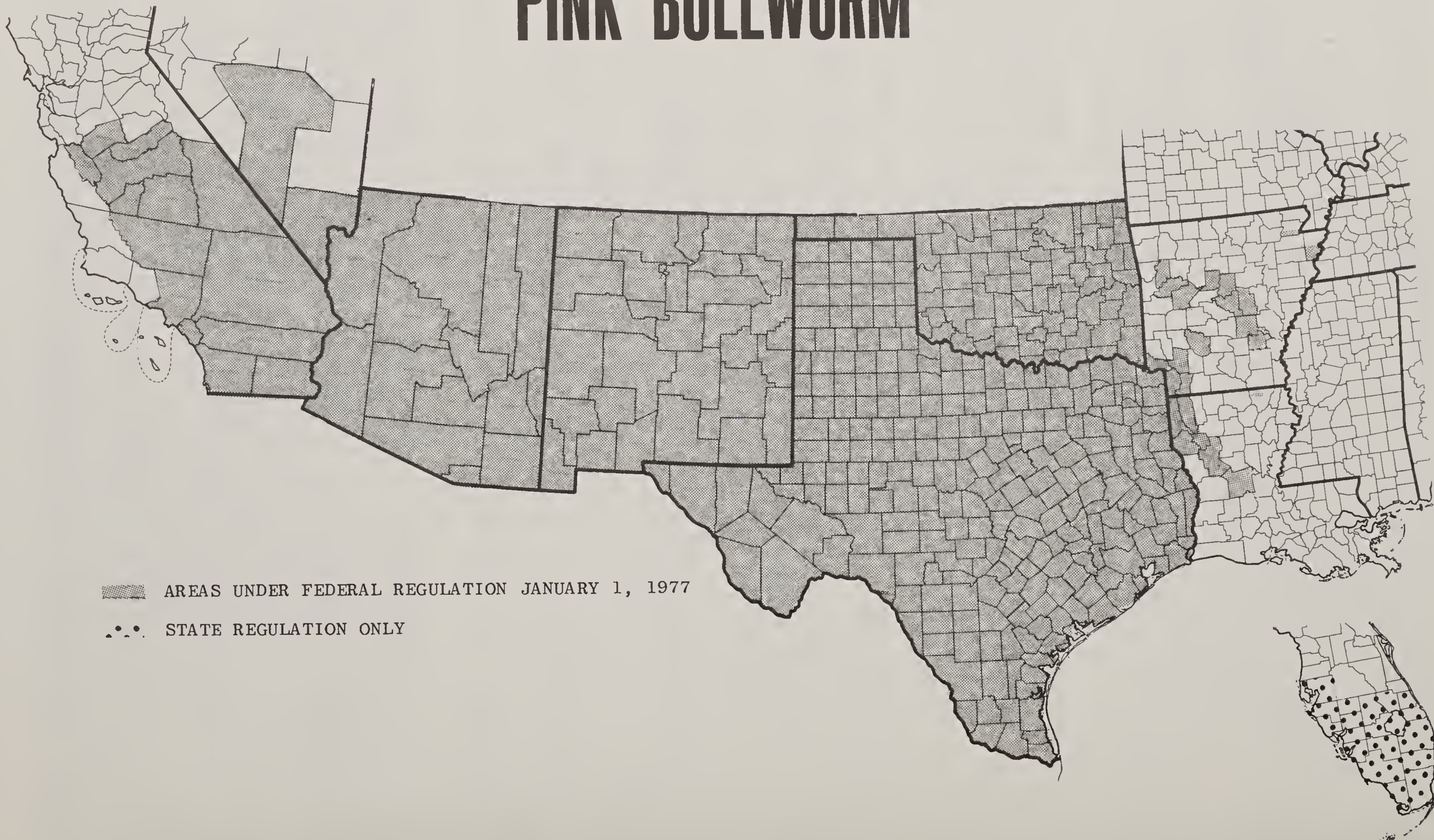
reduce the overwintering population. The pink bollworm hibernates in waste cotton left in the field, along roadsides, and at the gin; therefore, destruction of this material aids considerably in the control of this pest. Mandatory cultural control zones are in effect in the United States in the southern, central, and eastern section of Texas, and in regulated areas of Arkansas, Louisiana, Arizona, and California. Cultural practices used in pink bollworm control are effective in reducing the boll weevil carryover for the next year. Recommended control practices include the following:

1. Shorten the planting period and plant at the optimum time for a given locality. Use seeds of an early-maturing variety which have been culled, treated with a fungicide, and tested for germination.
2. Leave as thick a stand as has been recommended for the section and type of soil.
3. Produce the cotton in the shortest practicable time. Early-season control of certain insects has proved advantageous in some States but not in others. Practice early-season control where recommended by controlling the cotton aphid, the boll weevil, the cotton fleahopper, cutworms, thrips, and any other insects that may retard the growth and fruiting of young plants. Protection of early fruit will assure an early harvest.
4. Withhold late irrigation. Use defoliants or dessicants to hasten the opening of the bolls when the crop is mature.
5. Harvest cleanly. In areas where spindle pickers are used, final scrapping with a stripper is desirable. Use a cotton gleaner if appreciable cotton is left on the ground after harvest.
6. Shred and plow under cotton stalks and debris as soon as possible after harvest. Okra stalks and debris should be shredded and plowed under at the same time because this plant is a preferred secondary host.
7. In cold areas where winter irrigation is not feasible, leave stalks standing until lowest temperatures have occurred. This is to secure a maximum kill of pink bollworms in the bolls on the stalks. However, if a large amount of crop debris, such as seed cotton or locks, is on the soil surface, a high survival of the pest may result. When this condition exists, the stalks should be shredded and plowed under as early and as deeply as possible.
8. In warmer areas the growing of volunteer and stub cotton should not be permitted.

The flail-type shredder is recommended over the horizontal rotary type for pink bollworm control. The flail shredder will kill about 85 percent of the pink bollworms left in the field after harvest, compared with 55 percent for the horizontal rotary shredder. The residue should be plowed under as deeply as possible. Pink bollworm winter survival is highest in bolls on the soil surface and is six times as high in bolls buried only 2 inches as compared with bolls buried 6 inches deep. Before fruiting, all sprout and seedling cotton and okra developing after plowing should be destroyed to create a host-free period between crops. In arid areas, if the crop debris is plowed under in the late fall or early winter, the fields should be winter-irrigated to increase pink bollworm mortality.

<u>Control with insecticides</u>--Where infestations are heavy, crop losses from pink bollworm can be reduced by proper use of insecticides. One-half to 1 pound of azinphosmethyl, 0.6 to 1 pound of monocrotophos, or 2.0 to 2.5

PINK BOLLWORM



pounds of carbaryl per acre will control the pink bollworm. Monocrotophos (Azodrin) or carbaryl at the above dosages will control the boll weevil and bollworm. The use of certain insecticides for control of other cotton insects exerts a repressive effect on pink bollworm populations.

Saltmarsh Caterpillar and Other Arctiids

The saltmarsh caterpillar, _Estigmene acrea_ (Drury), is a late-season pest of cotton principally in western irrigated areas. It may be controlled with the following insecticides at the indicated dosages of technical material:

Sprays or dusts	Pounds per acre
carbaryl	2.0
diazinon	1.0
methyl parathion	1.0
trichlorfon	1.5

Occasionally, the yellow woollybear, _Diacrisia virginica_ (F.) and the hairy larvae of several other tiger moths, Arctiidae, including _Callarctia phyllira_ (Drury), _C. arge_ (Drury), and _C. oithona_ Strk., cause serious damage to cotton. Information is needed on their seasonal host plants, distribution, natural enemies, causes of serious outbreaks in cotton fields, life history, and control. (Determinations of species by specialists should always be obtained.)

Seedcorn Maggot, _Hylemya platura_ (Meigen)

The seedcorn maggot may seriously affect the stand of cotton, particularly when planting closely follows the turning under of a green-manure crop or other heavy growth. This insect may be controlled with 2 ounces of endrin mixed with a normally used fungicide and applied onto each 100 pounds of planting seed in a slurry. Seed should be treated immediately before planting.

Spider Mites

The following spider mites are known to attack cotton:

Carmine spider mite, _Tetranychus cinnabarinus_ (Boisduval)
Desert spider mite, _T. desertorum_ Banks
Fourspotted spider mite, _T. canadensis_ McGregor
T. yustis McGregor
Pacific spider mite, _T. pacificus_ McGregor
Schoene spider mite, _T. schoenei_ McGregor
Strawberry spider mite, _T. turkestani_ Ugarov and Nikolski
Tumid spider mite, _T. tumidus_ Banks
Twospotted spider mite, _T. urticae_ Koch and
T. ludeni Zacker

The species differ in their effect on the cotton plant and in their

reaction to miticides. Accurate identification of the species is essential. The use of organic insecticides for cotton insect control has been a factor in increasing the importance of spider mites as pests of cotton.

Table 2 lists the species of spider mites and the miticides that have been found to be effective in their control.

For control of some species and suppression of others at least 40 percent sulfur may be incorporated in dusts. Elemental sulfur cannot be incorporated in sprays applied at low gallonage, but other miticides may be substituted. Sulfur dust is more effective when finely ground and when applied at temperatures above 90°F. Thorough coverage is essential.

Some difficulty in control of spider mites has been experienced with ultra-low-volume applications of recommended miticides probably because of insufficient plant coverage.

Stink bugs

The following stink bugs are sometimes serious pests of cotton:

Brown stink bug, *Euschistus servus* (Say)
(also, the onespot stink bug, *E. variolarius* (Polisat de Beauvois))
Conchuela, *Chlorochroa ligata* (Say)
Dusky stink bug, *E. tristigmus* (Say) and *E. conspersus* (Uhler)
Green stink bug, *Acrosternum hilare* (Say)
Redshouldered plant bug, *Thyanta custator* (F.)
(also, *T. rugulosa* (Say), *T. pallidovirens spinosa* (Ruckers))
Say stink bug, *Chlorochroa sayi* Stal
Southern green stink bug, *Nezara viridula* (L.)
Western brown stink bug, *Euschistus impictiventris* Stal

The importance of these pests and the species involved vary from year to year and from area to area. The damage is confined principally to the bolls and results in reduced yields and lower quality of both lint and seed.

The following insecticides applied at the indicated dosages of technical material have given control of one or more species of stink bugs:

Sprays or dusts	Pounds per acre
carbaryl	1.25-2.5
endosulfan	1.0
methyl parathion	0.75-1.5
parathion	0.5-1.0
trichlorfon	1.0-1.5

Thrips

Thrips often injure cotton seedlings, especially in areas where vegetables, legumes, and small grains are grown extensively. The following species have been reported as causing this injury:

Flower thrips, *Frankliniella tritici* (Fitch)
(also, *F. exigua* Hood, *F. occidentalis* (Pergande), and *F. gossypiana* Hood)

Table 2.--Recommended dosages of miticides for control of specific species of spider mites

[Pounds per acre]

Miticide	Carmine	Desert	T. yustis	Pacific	Schoene	Strawberry	Tumid	Two-spotted	Ludeni
aldicarb[1]	0.6-1.0	0.6-1.0	0.6-1.0	--	--	0.6-1.0	--	0.6-1.0	--
carbophenothion	0.25-1.0	--	--	--	0.25-0.5	--	--	0.25-1.0	--
chlorobenzilate	--	--	--	1.0	1.0	1.0	--	1.0	--
demeton	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38
dicofol	--	0.8-1.6	--	0.8-1.0	--	0.8-1.6	--	0.8-1.6	--
dicrotophos	0.1-0.25	0.1-0.2	--	--	--	0.1-0.25	--	0.125-0.25	--
disulfoton[2]	0.5-1.0	0.5-1.0	--	--	--	0.5-1.0	--	0.5-1.0	--
ethion	0.25-1.5	0.25-0.75	0.25-1.0	--	0.25-1.0	0.25-0.5	--	0.25-1.5	--
methidathion	1.0	1.0	1.0	--	1.0	1.0	--	1.0	--
methyl parathion	--	0.6	--	--	0.6	--	0.6	0.6	--
monocrotophos	0.5-1.0	0.5-1.0	0.8-1.0	--	0.6-1.0	0.6-1.0	0.5-1.0	0.5-1.0	0.5-1.0
parathion	--	0.25-0.5	0.1-0.2	--	--	--	0.25-0.5	0.125-1.0	0.2
phorate[3]	0.5-1.5	0.5-1.5	--	--	--	1.0-1.5	--	0.5-1.5	--
propargite	--	--	--	0.8-1.6	--	0.8-1.6	--	0.8-1.6	--
sulfur	--	--	--	--	--	45-50	--	20-50	--

1/ In-furrow granule treatment at planting.
2/ In-furrow granule treatment at planting or 0.5 pound per hundredweight of planting seed.
3/ In-furrow granule treatment at planting or 1.3 to 1.5 pounds per hundredweight of planting seed.

Onion thrips, *Thrips tabaci* Lindeman
Sericothrips variabilis (Beach)
Tobacco thrips, *F. fusca* (Hinds)

In some areas cotton plants usually recover from thrips injury to seedlings; therefore, control is not recommended unless the stand is threatened. In other areas damage by thrips is more severe and control measures are generally recommended. Injury from thrips alone, or the combined injury of thrips and disease, may reduce or even destroy stands of young plants. A heavy infestation may retard plant growth and delay fruiting and crop maturity. Although thrips are predominantly pests of seedlings, damaging infestations sometimes occur on older cotton in certain areas.

The following insecticides at the indicated dosages of technical material are recommended, when the situation warrants their use.

Sprays or dusts	Pounds per acre
azinphosmethyl	0.08-0.4
carbaryl	0.35-1.0
dicrotophos	0.25
dimethoate	0.1-0.4
malathion	0.4-2.5
methyl parathion	0.12-0.5
phosphamidon	0.18-0.5
toxaphene	0.8-1.5

The following materials are effective when used as seed treatment or as in-furrow granule applications at planting at the indicated dosages of technical material:

	Pounds per acre	Pounds per hundredweight of seed
aldicarb	0.3-0.5	
disulfoton	0.6-1.0	0.25-0.5
monocrotophos		0.25-1.25
phorate	0.5-1.5	1.30-1.5

The bean thrips, *Caliothrips fasciatus* (Pergande), is an occasional mid-season to late-season pest of cotton in parts of California. Toxaphene at 2 to 3 pounds per acre gives satisfactory control when applied in either a spray or dust.

Caliothrips phaseoli (Hood) damaged cotton near Bard, Imperial County, California, in 1962.

Scirtothrips sp. causes severe crinkling of top leaves of cotton in localized areas of Arizona, Mississippi, and Texas.

Kurtomathrips morrilli Moulton was described in 1927 from specimens taken on cotton at Gila Bend, Arizona. It was collected at Seeley, California, from cotton on May 2, 1930, at Laveen, Arizona, on July 23, 1943, and was reported as causing severe injury to cotton at Gila Bend in July 1957.

Frankliniella occidentalis and *F. gossypiana* do not occur on cotton in the Eastern United States. In the West. *F. tritici* is of little importance on cotton and *F. fusca* does not occur.

Whitefringed Beetles, *Graphognathus* spp.

Whitefringed beetles are pests of cotton and many other farm crops in limited areas of Alabama, Arkansas, Florida, Georgia, Louisiana, Mississippi, North Carolina, South Carolina, and Tennessee. Infestations in recent years have been discovered in Maryland, Virginia, and Texas. The larvae feed on the roots of young plants.

When applied to the foliage as recommended for the control of cotton insects, toxaphene will reduce adult populations; however, the principal benefit is the reduction of subsequent larval populations.

Wireworms

Several species of wireworms are associated with cotton. Damage is caused by the sand wireworms, *Horistonotus uhlerii* Horn, in South Carolina and Louisiana, and by the Pacific Coast wireworm, *Limonius canus* LeConte, in California. Adults of the tobacco wireworm (or spotted click beetle), *Conoderus vespertinus* (F.), are frequently found on the cotton plant, and the larvae may cause damage to cotton. Wireworms, together with false wireworms and the seedcorn maggot, sometimes prevent the establishment of a stand. To control these insects, treat the seed with 2 ounces of endrin, plus a normally used fungicide per 100 pounds in a slurry.

Approved crop-rotation practices, increased soil fertility, and added humus help to reduce damage to cotton by the sand wireworm.

Yellowstriped Armyworm, *Spodoptera ornithogalli* (Guenee) and Western Yellowstriped Armyworm, *S. praefica* Grote

These insects sometimes cause considerable damage to cotton. The yellowstriped armyworm is difficult to kill with insecticides. However, trichlorfon at 1.5 pounds and methyl parathion at 1 to 1.5 pounds per acre give good control of large and small larvae.

The western yellowstriped armyworm, which attacks cotton in California, is controlled with trichlorfon at 0.75 to 1.0 pounds and toxaphene at 2-3 pounds per acre. Migrations from surrounding crops may be stopped with barriers of 5 percent trichlorfon or 5 pet ent carbaryl at 2 pounds per 100 linear feet.

MISCELLANEOUS INSECTS

The brown cotton leafworm, *Acontia dacia* Druce, was collected from three counties in Texas in 1953. Since then, damaging infestations have occurred in some years over wide areas of Texas and in Louisiana. Recoveries have been reported from Arkansas. This pest may be controlled with azinphosmethyl at 0.25 pound, malathion at 0.25 pound, and parathion at 0.125 pound per acre.

Several *Anomis* leafworms are known to occur in the cotton-growing regions of Africa; Asia; Australia; North, Central, and South America; and the East

and West Indies. Three species--*A. erosa* Hubner, *A. flava fimbriago* (Stephens) and *A. texana* Riley--occasionally damage cotton in the United States. They are often mistaken for the cotton leafworm and are sometimes found on the same plants with it. Although specific control data are lacking, the insecticides recommended for control of the cotton leafworm might also be effective against *Anomis* leafworms.

First generation adults of the spotted cucumber beetle, *Diabrotica undecimpunctata howardi* Barber, were heavier than usual on several crops, including cotton in western Tennessee in July 1973. Some light damage is usually expected on all infested crops except cotton. Pests were numerous enough to cause light to moderate damage to squares and blooms. Adults feed in the ovary of the bloom, resulting in loss of the young boll. Some feeding on squares was noted in all fields surveyed. Damage was light.

Root aphids known to attack cotton are the corn root aphid, *Aphis maidiracidis* Forbes, *Smynthurodes betae* (Westwood), and *Rhopalosiphum rufiabdominalis* (Sasaki). So far as is known, injury before 1956 was confined to the eastern seaboard. *S. betae* destroyed spots of cotton up to 1-1/2 acres in fields in Pemiscot County, Mo, in 1956. In 1961, root aphids caused some damage to cotton in the northeastern counties of North Carolina and Arkansas. In 1975, *S. betae* killed 20 percent of stand of seedling cotton at Roswell, Chaves County, New Mexico, a new State record. Several species of ants are known to be associated with root aphids, the principal one being the cornfield ant, *Lasius alienus* (Foerster). Chemical control of root aphids has been directed at this ant. Some new materials are known to be effective as soil insecticides and might be tested against root aphids attacking cotton. Root aphids injure cotton chiefly in the seedling stage. Since cotton in this stage shows injury without any evidence of insects being present, the underground parts should be examined carefully. Ant mounds at the base of these plants indicate the presence of root aphids.

The cowpea aphid, *Aphis craccivora* Koch, the green peach aphid, *Myzus persicae* (Sulzer), and the potato aphid, *Macrosiphum euphorbiae* (Thomas), are common on seedling cotton. Cotton is not believed to be a true host of these species. In 1963, *A. craccivora* caused severe and permanent stunting of cotton plants in the San Joaquin Valley of California.

The garden springtail, *Bourletiella hortensis* (Fitch) has caused injury to cotton locally in Hertford County, North Carolina. Another springtail, *Entomobrya unostrigata* Stach, has occasionally damaged seedling cotton over a wide area of the southern high plains of Texas and New Mexico.

The whitelined sphinx, *Hyles lineata* (F.), occasionally occurs in large numbers in uncultivated areas and migrates to cotton. It may be controlled on cotton with dusts or sprays of toxaphene at 2 to 3 pounds per acre. Migrations may be stopped with barrier strips of 20 percent toxaphene or physical barriers.

The cowpea curculio *Chalcodermus aeneus* Boheman, sometimes causes damage to seedling cotton.

A curculionid, *Compsus auricephalus* (Say), damaged young cotton plants and foliage in Grady County, Oklahoma, in 1961. It also appeared in large numbers in cotton fields in Pope County, Arizona. In 1963, heavy populations caused considerable foliage damage to young plants in localized areas of Grimes, Robertson, and Brazos Counties in Texas and in Obion and Lake Counties in Tennessee. A curculionid, *Conotrachelus erinaceus* LeConte, caused damage to stems of seedling cotton in isolated instances in Marion

County, Alabama, in 1962. A curculinoid, *Otiorhynchus cribricollis* Gyllenhal caused spotted heavy damage to cotyledons of seedling cotton in New Mexico in 1967 and 1972.

The cotton stainer, *Dysdercus suturellus* (Herrich-Schaffer), is found within the United States in Florida only. However, probably owing to mistaken identity, the literature also records it from Alabama, Georgia, and South Carolina. No work on control has been formally reported in recent years, but observations indicate that dusts containing 10 percent toxaphene will control insects of this genus.

Several leafhoppers of the genus *Empoasca* are often abundant on cotton in many sections of the Cotton Belt. Serious injury has been reported only in California, however, and this was caused by two species, *E. solana* DeLong (southern garden leafhopper) and *E. fabae* (Harris) (potato leafhopper). These species are known to be phloem feeders on some crops and cause damage typical of this type of feeding on cotton. Sprays of trichlorfon (Dylox) at 1 pound, malathion at 1 pound, parathion (ethyl) at 0.5 pound, or demeton at 0.25 pound per acre have given satisfactory control.

The striped blister beetle, *Epicauta vittata* (F.), sometimes causes severe foliage damage in small localized areas. Damage usually results when weeds, which are preferred host plants, are cleaned out of cotton. Total loss of foliage may result in small areas before the insects move out of the field. Spot treatment with the organochlorines is usually effective for control of outbreaks.

Field crickets, *Gryllus* spp., occasionally feed on cotton bolls and seedling plants in the Imperial Valley of California and in Arizona. During periods of drought late in the season, they may feed on the seed of open bolls, especially in the Delta sections of Arkansas, Louisiana, and Mississippi. This feeding is usually done at night as the crickets hide during the day in deep cracks in the soil. Crickets may be controlled with 5 per cent carbaryl or trichlorfon bait at 30 pounds per acre.

Serpentine leafminers, *Liriomyza* spp., and *L. pictella* (Thomson) in California, have been present in large numbers in some areas during the last few years. Drought conditions favor infestations of these pests. Heavy infestations may result in considerable leaf shed. Infestations are brought under control by rain or irrigation. Field tests at Waco, Texas, showed that the best reductions were obtained with parathion (ethyl) at 1.0 pound per acre. Seed treatment of phorate at 0.25 to 0.5 pound, and disulfoton at 1 pound per acre are also effective 4 to 6 weeks after planting.

The corn silk beetle, *Calomicrus brunneus* (Crotch), has been reported as a pest of cotton in localized areas of South Carolina, Georgia, Alabama, Mississippi, and Louisiana, but little is known about it.

Damage to cotton by periodical cicadas, *Magicicada* spp., in the United States was first reported in 1905. Damage is caused by the deposition of eggs in the stems of young plants, branches of older plants, and occasionally in leaf petioles. The parts of the plant above the oviposition puncture usually die. Growth below the puncture results in low bushy plants. Severe local damage to cotton by *Diceroprocta vitripennis* (Say) occurred in the river bottoms of nine counties in Arkansas in 1937. A cicada, undetermined species, caused light damage to cotton in some areas in Maricopa County, Arizona, in 1961.

Leaf beetles of the genus *Colaspis* are widespread and often found on cotton, frequently on the foliage, or near the base of squares and bolls

where they usually feed on the bracts surrounding them.

The harlequin bug, Murgantia histrionica (Hahn), heavily infested a few cotton fields in Graham County, Arizona, in August 1959. Feeding was similar to that of other stink bugs. No immature stages were noted.

The barberpole caterpillar, Mimoschima rufofascialis (Stephens), a pyralid larva, is reported occasionally attacking cotton bolls in Imperial and San Joaquin Valleys of California. It also has been reported from Arizona, Oklahoma, and Texas.

Bugs of the genus Nysius, N. ericae (Schilling), Xyonysius californicus Stal, and N. raphanus Howard, commonly called false chinch bugs, frequently migrate to cotton from adjacent weed hosts. Stands of seedling cotton may be destroyed by adults and nymphs. Methyl parathion and parathion are effective at 0.5 pound per acre.

Tree crickets, Oecanthus spp., infestations caused alarm to some southwestern Oklahoma cotton growers in mid-July 1958. Approximately 3-percent lodging occurred in the Blair area. There is evidence that this group of insects may be predaceous on aphids.

The European corn borer, Ostrinia nubilalis (Hubner), was first reported on cotton in the United States during 1955. The first report came from Franklin County, Tennessee, where a few plants near the edge of a field were severely damaged. This was on July 3 in a 3-acre field adjacent to one that was in corn the previous year. The cotton was only 8 to 10 inches high, and the larvae had entered the stems 2 to 6 inches from the ground and burrowed up through their centers. In August light infestations were reported in cotton in Dunklin, New Madrid, Pemiscot, Butler, Stoddard, and Mississippi Counties in Missouri, and in Madison County, Tennessee. The borers were found boring into the upper third of the stems, and second- and third-instar larvae were attacking small bolls. These records were of special interest because the European corn borer is apparently spreading in the Cotton Belt. No reports of this insect on cotton were received during 1956-1957. In 1958 it was found boring in cotton stalks in Autauga and Madison Counties, Alabama, and in Washington County, Mississippi, in late July. In 1959 as many as 10 percent of the plants were infested in a 10-acre field of cotton in Etowah County, Alabama. The field was planted to corn in 1958. It was also found in Madison Parish, Louisiana, in 1959. Damage was confined to the terminal 6 to 8 inches of the plant. Other infestations were noted in cottonfields in Autauga, Alabama. In 1961 larvae were found in cotton in Hardeman, Lincoln, and Fayette Counties in southern Tennessee. In 1966 larvae were found in cotton in Florence, South Carolina. In other parts of the world, particularly in Russia, Turkistan, and Hungary, it has been reported as a serious pest of cotton. One reference states, "In Turkistan it is principally cotton which is attacked by the larvae and in which they bore long tunnels in the upper part of the stem." Entomologist and other interested persons throughout the Cotton Belt should be on the alert to detect its presence and, whenever possible, record the type and degree of injury, seasonal and geographical distribution, and control measures that might be of value.

The Fuller rose beetle, Pantomorus cervinus (Boheman), occasionally is a pest of cotton. It is a leaf feeder and usually attacks cotton in the early season, causing ragging of the leaves and partial defoliation. It overwinters as an adult in about the same habitat as the boll weevil. Examinations of surface woods trash for hibernating boll weevils often reveal specimens of

the Fuller rose beetle. It has been reported from cotton in Georgia more frequently than from any other area.

The stalk borer, Papaipema nebris (Guenee), is widely distributed east of the Rocky Mountains. It attacks many kinds of plants, including cotton, and is so destructive that one borer in a field may attract attention. The borers are most likely to be noted near the edges of cottonfields. Light marginal injury occurred in scattered fields in Missouri during June 1957. It was also reported as causing some injury to cotton in Mississippi and Tennessee in 1956. In 1961 it caused some damage along the edges of many cottonfields in western and southern counties in Tennessee. It is sometimes mistaken for the European corn borer. Clean cultivation and keeping down weed growth help to hold them in check. The use of stalk shredders early in the fall should reduce their numbers.

A white grub, Phyllophaga ephilida (Say), was reported to have destroyed 5 acres of cotton in Union County, North Carolina, during 1956. As many as 20 larvae per square foot were found. P. zavalana Reinhard is also reported to be a pest of cotton in the Matamoras area of Mexico, where the adults feed on foliage, particularly in the seedling stage. It is known to occur in Zavala and Dimmit Counties of Texas. P. cribrosa (LeConte), sometimes known as the "4 o'clock bug" in west Texas, has also been feeding on young cotton in that area. Moderate damage was caused to young cotton plants in the Arkansas Delta area in 1962 by larvae of P. implicita (Horn).

The cotton stem moth, Platyedra subcinerea (Haworth), a close relative of the pink bollworm, was first discovered in the United States in 1951, when larvae were found feeding in hollyhock seed in Mineola, Long Island, New York. It is recorded as a pest of cotton in Iran, Iraq, Morocco, Transcaucasia, Turkistan, and the U.S.S.R., and as feeding on hollyhock and other malvaceous plants in England, France, and central and southern Europe. Collections made in 1953 extended its known distribution in this country to a large part of Long Island and limited areas in Connecticut and Massachusetts. Extensive scouting during 1954 disclosed that it had reached 11 counties in four States as follows: Hartford and New Haven, Conneticut; Essex and Plymouth, Massachusetts; Monmouth, Ocean, and Union, New Jersey; Westchester and all counties of Long Island (Nassau, Queens, and Suffolk), New York. There had been no reported spread since 1954 until 1965, when it was reported from Rockingham County, New Hampshire. Although this species has not been found in the Cotton Belt in the United States it is desirable to keep on the lookout for it on cotton, hollyhock, and other malvaceous plants. In 1956 it was collected from a natural infestation on cotton growing on the laboratory grounds at Farmingdale, New York.

A giant appletree borer, Prionus sp., caused isolated root damage to cotton in one county in Arkansas in 1962.

Larvae of the roughskinned cutworm, Proxenus mindara Barnes and McDonnough, cut bolls from lodged plants by feeding at the boll base in a cottonfield at Shafter, California, in 1964.

Several of the leaf rollers, Tortricidae, occasionally damage cotton. Platynota stultana (Walsingham) and P. rostrana (Walker) are the species most commonly recorded, but P. flavedana (Clemens) and P. idaeusalis (Walsingham) have also been reported. These species are widely distributed and have many host plants. P. stultana has at times been a serious pest of cotton in the Imperial Valley of California and part of Arizona and New Mexico. Trichlorfon

(Dylox) at 1 pound or carbaryl (Sevin) at 2 pounds per acre have satisfactorily controlled the species that occur on cotton in California.

Heavy feeding on cotton by the Japanese beetle, *Popillia japonica* Newman, was reported in Sampson County, North Carolina, in 1961. Adults of the Japanese beetle caused 30- to 35-percent defoliation of cotton plants in fields in the more heavily infested areas in North Carolina in 1970.

Adults of a buprestid beetle, *Psiloptera drummondi* (Laporte and Gory), occasionally cause damage to cotton. The damage consists of partly girdled terminals that break over and die.

The pink scavenger caterpillar, *Sathrobrota rileyi* (Walsingham), is one of several insects that resemble the pink bollworm and is sometimes mistaken for it by laymen. The larva is primarily a scavenger in cotton bolls and cornhusks that have been injured by other causes.

The cotton square borer, *Strymon melinus* (Hubner), occurs throughout the Cotton Belt but rarely causes economic damage. The injury it causes to squares is often attributed to the bollworm.

The palestriped flea beetle, *Systena blanda* Melsheimer, the elongate flea beetle, *S. elongata* (F.) and *S. frontalis* (F.), sometimes cause serious damage to seedling cotton in some areas. They can be controlled with endrin at 0.1 pound, and toxaphene at 2 to 3 pounds per acre. The sweetpotato flea beetle, *Chaetocnema confinis* Crotch, was found injuring seedling cotton in the Piedmont section of South Carolina in May 1954. The striped flea beetle, *Phyllotreta striolata* (Fabricius), caused damage to cotton in Alabama in 1959. Other species of flea beetles have been reported from cotton, but records regarding the injury they cause are lacking. When flea beetle injury to cotton is observed, specimens should be submitted to specialists for identification, with a statement regarding the damage they cause, the locality, and the date of collection.

The bandedwing whitefly, *Trialeurodes abutilonea* (Haldeman), the greenhouse whitefly, *T. vaporariorum* (Westwood), and the sweetpotato whitefly, *Bemisia tabaci* (Gennadius), are usually kept in check by parasites and diseases, but occasionally may be serious pests late in the season. *Bemisia tabaci* is reported to be a vector of the leaf crumple virus of cotton. The bandedwing whitefly has been a problem in Louisiana since 1964 and infestations have increased in Mississippi, Alabama, Arkansas, Oklahoma, and Georgia since 1972. The bandedwing whitefly may be controlled with monocrotophos in a spray at 0.25 to 1.0 pound per acre.

The greenhouse leaftier, *Udea rubigalis* (Guenee), also known as the celery leaftier, has occasionally been abundant on cotton in the San Joaquin Valley. Despite the heavy populations, damage was generally slight and restricted to foliage on the lower third of the plants in lush stands. In the few places where it was necessary to control this pest, endrin at 0.4 pound per acre in a dust or spray was effective. This pest caused damage in three fields near Yuma, Arizona, in 1964.

The false celery leaftier, *Udea profundalis* (Packard), caused considerable defoliation of cotton in some fields in Tulare, Kings, and Fresno Counties, California, in 1962. Control was difficult because of the insect's feeding habits on the lower part of plants within a web. Carbaryl (Sevin) at 2 pounds or trichlorfon at 1.0 pound per acre were effective against this pest.

Damage to cotton stalks by termites, undetermined species, was reported in western Tennessee in 1961, and in previous years in Texas. Termites,

Reticulitermes sp. (family Rhinotermitidae), partly destroyed a stand of cotton in Little River County, Arkansas, in 1961.

INSECTS IN STORED COTTONSEED AND SEED COTTON

Insect infestations in cottonseed during storage can be minimized if proper precautions are followed. Cottonseed and seed cotton should be stored only in a bin or room thoroughly cleaned of all old cottonseed, grain, hay, or other similar products in which insects that attack stored products are likely to develop. Among the insects that cause damage to stored cottonseed or to cottonseed meal are the cigarette beetle, Lasioderma serricorne (F.), the Mediterranean flour moth, Anagasta kuehniella (Zeller), the almond moth, Cadra cautella (Walker) and the Indian meal moth Plodia interpunctella (Hubner). Other insects commonly found in cottonseed are the flat grain beetle, Cryptolestes pusillus (Schonherr), the red flour beetle, Tribolium castaneum (Herbst), and the sawtoothed grain beetle, Oryzaephilus surinamensis (L.). Malathion is registered as a seed treatment for cottonseed. Seed so treated should not be used for food or feed. The pink bollworm, Pectinophora gossypiella (Saunders), may be found in stored cottonseed, but such infestations would be present in the seed before they are stored.

INSECT IDENTIFICATION

Prompt and accurate identification of insects and mites is a necessary service to research and to the control of cotton insects. Applied entomologists owe much to taxonomists for services often rendered on a volunteer basis.

Approved common names are convenient and useful. Local or nonstandard common names create confusion. Entomologists are urged to submit common names to the ESA Committee on Common Names of Insects for consideration, where such are needed.

Research in taxonomy has been productive of new developments. Major changes have been made in classification of spider mites attacking cotton. Several species of thrips and plant bugs have recently been added to the list of cotton pests. The Melanoplus mexicanus group of grasshoppers has been completely revised. Heliothis virescens (F.) has been accurately defined. Several scientific names have been changed.

COTTON-INSECT SURVEYS

The importance of surveys to an overall cotton-insect control program has been clearly demonstrated. Surveys conducted on a cooperative basis by State and Federal agencies in most of the major cotton-growing States have developed into a broad, up-to-date advisory service for the guidance of county agents, ginners, farmers, and other leaders of agriculture who are interested in the distribution and severity of cotton-insect pests, as well as industry that serves the farmers by supplying insecticides. As a result of this survey work, farmers are forewarned of the insect situation, insecticide applications are better timed, and losses are materially reduced below what they would be without the information thus gained. The surveys also help to direct insecticides to areas where supplies are critically needed.

It is recommended that cotton-insect surveys be continued on a permanent basis, that they be expanded to include all cotton-producing States, and that the survey methods be standardized.

It is further recommended that the greatest possible use be made of fall, winter, and early spring surveys as an index to the potential infestation of next season's crop.

Each year more people are being employed by business firms, farm operators, and others to determine cotton-insect populations. State and Federal entomologists should assist in locating and training personnel that have at least some basic knowledge of entomology.

Whenever possible, voluntary cooperators should be enlisted and trained to make field observations and records and to submit reports during the active season.

Surveys to detect major insect pests in areas where they have not previously been reported may provide information that can be used in restricting their spread or in planning effective control programs. The survey methods may include (1) visual inspection, (2) use of traps containing aromatic lures, or sex and aggregating pheromones, (3) use of light traps, (4) use of mechanical devices such as gin-trash machines, (5) examination of glass windows installed in lint cleaners used in ginning, and (6) portable vacuum devices for sampling insect populations. The methods of making uniform survey for several of the important insects are described below.

Light traps have provided valuable survey information for the following cotton insects: Beet armyworms, bollworms, brown cotton leafworm, cabbage looper, cotton leafworms, cutworms, fall armyworm, garden webworm, pink bollworm, saltmarsh caterpillar, whitelined sphinx, yellowstriped armyworm, and yellow woollybear.

Pheromone traps have provided valuable survey information on the boll weevil, bollworm, pink bollworm, tobacco budworm, cabbage looper, and fall armyworm.

Boll Weevil

Surveys to determine winter survival of the boll weevil are made in several States. Counts are made in the fall soon after the weevils have entered hibernation and again in the spring before they emerge from winter quarters. A standard sample is 2 square yards of surface woods trash taken from the edge of a field where cotton was grown the previous season. Three samples are taken from each of 30 locations in an area, usually consisting of three or four counties.

In the main boll weevil area, counts are made on seedling cotton to determine the number of weevils entering cottonfields from hibernation quarters. The number per acre is figured by examining the plants on 50 feet of row in each of five representative locations in the field and multiplying the total by 50. Additional counts are desirable in large fields.

Square examinations are made weekly after the plants are squaring freely or have produced as many as three squares per plant. While walking diagonally across the field, you pick 100 squares, one-third grown or larger; take an equal number from the top, middle, and lower branches. Do not pick squares from the ground or flared or dried-up squares that are hanging on the plant. The number of squares found to be punctured is the percentage of infestation. To obtain a total of 100 to 500 squares, an alternate method is

to inspect about 25 squares in each of several locations distributed over the field. The number of squares inspected depends upon the size of the field and the surrounding environment. The percentage of infestation is determined by counting the punctured squares. In both methods all squares that have egg or feeding punctures should be counted as punctured squares.

The point-sample method developed by Arkansas entomologists consists of the following procedures: Select a representative area in a field and mark a starting point on a row. Examine the first 50 green squares that are 1/4 inch or larger in diameter for boll weevil punctures. Count those that are punctured and step off the feet of row required for the 50 squares. Four such counts, a total of 200 squares, are adequate for uniform fields up to 40 acres in size. Fields that are larger or that are not uniform should be considered as separate fields with four counts made in each. The percentages of punctured squares, number of squares per acre, and number of punctured squares per acre can be determined from the point sample information.

A conversion table for usual row widths in an area with various numbers of row feet, 1 to 250, required for a 200 square count is prepared for ease in determining the number of squares and punctured squares per acre. Example: If 10 feet of a 40-inch row are required for 200 squares, there are 261,000 squares per acre. If 50 percent of the squares are punctured, there are 130,500 punctured squares per acre.

Bollworms

Examinations for bollworm eggs and larvae should be started as soon as the cotton begins to square and repeated every 5 days, if possible, until the crop has matured. In some areas it may be necessary to make examinations for bollworm damage before cotton begins to square. While walking diagonally across the field, examine the top 3 or 4 inches of the main-stem terminals, including the small squares, of 100 plants. Whole-plant examinations should be made to insure detection of activity not evident from terminal counts. Eggs of cutworms, cabbage looper, and other lepidopterous species are sometimes mistaken for those of the bollworm.

The point-sample method developed by Arkansas entomologists consists of the following procedures: Select a representative area in a field and mark a starting point on a row. Examine the first 50 squares for bollworm damage. Count those that are damaged and step off the feet of row required for the 50 squares. Four such counts, a total of 200 squares, are adequate for uniform fields up to 40 acres in size. Fields that are larger or that are not uniform should be considered as separate fields with four counts made in each. The percentage of punctured squares, number of squares per acre, and number of damaged squares can be determined from the point sample information.

A conversion table for usual row widths in an area with various numbers of row feet, 1 to 250, required for a 200 square count is prepared for ease in determining the number of squares and damaged squares per acre. Example: If 20 feet of a 40-inch row are required for 200 squares, there are 131,000 squares per acre. If 10 percent of the squares are damaged, there are 13,100 damaged squares per acre.

Cotton Aphid

To determine early-season aphid infestation, walk diagonally across the

field, observe many plants, and record the degree of infestation as follows:

None---------if none is observed.
Light-------if aphids are found on an occasional plant.
Medium------if aphids are present on numerous plants and some of the leaves curl along the edges.
Heavy-------if aphids are numerous on most of the plants and the leaves show considerable crinkling and curling.

To determine infestations on fruiting cotton you begin at the margin of the field and, while walking diagonally across it, examine 100 leaves successively from near the bottom, the middle, and the top of the plants. Record the degree of infestation, as follows, according to the average number of aphids estimated per leaf.

None---------0
Light-------1 to 10
Medium------11 to 25
Heavy-------26 or more

Cotton Fleahopper

Weekly inspections should begin as soon as the cotton is old enough to produce squares. In some areas inspections should be continued until the crop is set. While walking diagonally across the field, examine 3 or 4 inches at the top of the main-stem terminals of 100 cotton plants--counting both adults and nymphs. Use of sequential sampling will usually reduce the number of terminals needed to determine population levels with no loss in accuracy. To determine populations white or black cloth sheets are placed under plants, which are thoroughly shaken. Ten 3-row foot samples are taken at random within a field. Populations are recorded on a per-acre basis.

Cotton Leafworm

The following levels of leafworm infestation, on the basis of ragging and the number of larvae per plant, are suggested for determining damage:

None---------if none is observed.
Light-------if 1 or only a few larvae are observed.
Medium------if 2 to 3 leaves are partly destroyed by ragging with 2 to 5 larvae per plant.
Heavy-------if ragging of leaves is extensive with 6 or more larvae per plant, or if defoliation is complete.

Lygus Bugs and Other Mirids

Inspections should be made at 3- to 7-day intervals beginning at pinhead square stage and continuing until early September. Infestations should be determined by making a 50- to 100-sweep count at each of four or more locations. Sweeping is accomplished by passing a 15-inch net through the tops of the plants in one row, the lower edge of the net is slightly preceding the upper edge. Contents of the net should be examined carefully to avoid over-

looking very small nymphs. The plant terminal inspection as described for the cotton fleahopper may also be used. During hot summer weather, sweeping should not be made between 11:30 a.m., and 3:00 p.m., since lygus bugs are prone to move into plant cover to avoid heat.

To determine populations white or black cloth sheets are placed under plants which are thoroughly shaken. Ten-3 row foot samples are taken at random within a field. Populations are recorded on a per-acre basis.

Pink Bollworm

Counts to determine the heavy degree of infestation in individual fields may be made early in the season by inspecting blooms and later by inspecting bolls. Bloom inspections for comparing yearly early-season population should be made so as to obtain an estimate of the number of larvae per acre.

Bloom inspection--Five days after the first bloom appears, but not later than 15 days, check for number of larvae per acre as follows: Step off 300 feet of row (100 steps) and count the rosetted blooms at five representative locations in the field (1,500 feet). Add the number of rosetted blooms from these five locations and multiply by 10 to obtain the number of larvae per acre.

Boll inspection--Check weekly for the percentage of bolls infested as follows: Walk diagonally across the field and collect at random 100 bolls (2/3 grown or larger). Crack the bolls and examine the inside of the hull for tunnels made by young larvae. Where tunneling is not found, check lint and seed for evidence of larval feeding. Record the number of bolls infested on a percentage basis.

Other inspection techniques--There are other inspection methods that are helpful in directing control activities against the pink bollworm. They make possible the detection of infestations in previously uninfested areas and the evaluation of increases or decreases as they occur in infested areas. They are also used to determine the population of larvae in hibernation and their carryover to infest the new cotton crop.

1. Inspection of lint cleaner: During the ginning process the free larvae remaining in the lint are separated in the lint cleaners, and a substantial number of them are thrown and stuck on the glass inspection plates. All the larvae recovered are dead. For constant examination at a single gin, wipe off the plates and examine after each bale is ginned. In this way the individual field that is infested may be determined. For general survey, make periodic examinations to detect the presence of the pink bollworm in a general area.

2. Examination of debris: Between January and the time squares begin to form in the new crop, examine old bolls or parts of bolls from the soil surface in known infested fields. Examine the cotton debris from 50 feet of row at five representative points in the field for number of living pink bollworms. Multiply by 50 to determine number of living larvae per acre. Such records when maintained from year to year provide comparative data that may be used in determining appropriate control measures.

3. Use of sex lure traps: Traps containing a sex attractant extracted from the tips of abdomens of female pink bollworm moths were highly effective in trapping male moths. This method was replaced by a synthetic attractant,

hexalure, which was effectively used both for detection of infestations and to time the application of insecticides for control of the pest. This method of control resulted in a substantial financial saving to growers. Recently the true sex attractant, gossyplure, has been synthesized and is now being used in detection and in research as a male confusant in control of the pink bollworm as well as in early-season mass trapping programs. Gossyplure has proven more efficient in both detection and in the timing of insecticide applications in some areas.

Spider Mites

Examine 25 or more leaves from representative areas within a field taken successively from near the bottom, the middle, and the top of the plants. Record, according to the average number of mites per leaf, the degree of infestation as follows:

None--------0
Light-------1 to 10
Medium------11 to 25
Heavy-------26 or more

Thrips

While walking diagonally across the field, observe or inspect the plants, and record the damage as follows:

None--------if no thrips or damage is found.
Light-------if newest unfolding leaves show only a slight brownish tinge along the edges with no silvering of the underside of these or older leaves, and only an occasional thrips is seen.
Medium------if newest leaves show considerable browning along the edges and some silvering on the underside of most leaves, and thrips are found readily.
Heavy-------if silvering of leaves is readily noticeable, terminal buds show injury, general appearance of plants is ragged and deformed, and thrips are numerous.

Plants beaten over a thrips box or over a piece of cloth may be used to determine numbers of thrips per plant.

Predators

Populations of predators may be estimated by counting those seen while examining leaves, terminals, and squares for pest insects. When special counts for predators only are made, examination of whole plants is more efficient in estimating populations. To determine populations, white or black cloth sheets are placed under plants which are thoroughly shaken. Ten 3-row foot samples are taken at random within a field. Populations are recorded on a per-acre basis.

SOME MAJOR COTTON PESTS OCCURRING IN OTHER COUNTRIES AND HAWAII THAT MIGHT BE INTRODUCED INTO THE CONTINENTAL UNITED STATES

Some major pests of cotton in other countries and Hawaii that do not occur in the continental United States and that might be accidentally introduced into this country at any time are listed below. Cotton farmers, cotton scouts, county agents, entomologists, and others should be alerted to the possibility of these pests becoming introduced into this country and should collect and submit for identification any insect found causing damage to cotton if its identity is in doubt.

FAMILY AND SCIENTIFIC NAME	COMMON NAME	PLANT PARTS DAMAGED	DISTRIBUTION
Cicadellidae			
Empoasca lybica (Bergevin)	Cotton jassid	Foliage	Africa, Spain, and Israel
Pseudococcidae			
Maconellicoccus hirsutus Green	Hibiscus mealybug	Foliage, terminals	Asia and Africa
Curculionidae			
Amorphoidea lata Motschulsky	Philippine cotton boll weevil	Squares, bolls	Philippine Islands
Anthonomus vestitus Boheman	Peruvian cotton square weevil	Similar to *A. grandis*	Peru and Ecuador
Eutinobothrus brasiliensis (Hambleton)	Brazilian cotton borer	Stems, roots	Brazil and Argentina
Pempherulus affinis (Faust)	Cotton stem weevil	Stems	Southeastern Europe and Philippine Isl.
Lygaeidae			
Oxycarenus hyalinipennis Costa	Cottonseed bug	Seed, lint	Africa, Asia and Philippine Islands
Miridae			
Horcias nobilellus (Berg)	Cotton plant bug	Terminals, squares, young bolls	Brazil, Argentina, and Paraguay
Noctuidae			
Diparopsis castanea Hampson	Red bollworm	Bolls	Africa

FAMILY AND SCIENTIFIC NAME	COMMON Name	PLANT PARTS DAMAGED	DISTRIBUTION
Earias insulana (Boisduval)	Spiny bollworm	Young growth, bolls	Africa, Asia Australia, and Southern Europe
Spodoptera littoralis (Boisduval)	Egyptian cotton leafworm	Foliage, squares	Africa
Spodoptera litura (Fabricius)	Old World cotton leaf-worm	Foliage, squares	Asia, Southern Europe, Hawaii, and Pacific Isl.
Heliothis armigera (Hubner)	Cotton bollworm	Terminals, squares, bolls	Australia, Asia, Southern Europe
Heliothis punctigera (Wallings)	Budworm	Terminals, squares, bolls	Australia
Sacadodes pyralis Dyar	False pink bollworm	Squares, bolls	Central and South America
Olethreutidae			
Cryptophlebia leucotreta (Meyrick)	False codling moth	Bolls	Africa
Pyralidae			
Sylepta derogata (F.)	Cotton leaf roller	Foliage	Africa, Asia Australia, and Pacific Islands
Pyrrhocoridae			
Dysdercus peruvianus Guerin	Peruvian cotton stainer	Bolls	Brazil, Columbia, Peru, and Venezuela
Gelechiidae			
Pectinophora scutigera Holdaway	Pinkspotted bollworm	Bolls	Australia
Pexicopia malvella (Hbn.)		Bolls	Pakistan

CONFEREES

One hundred and seventeen entomologists, and associated technical workers concerned with cotton insect research and control participated in this Conference. They were from the agricultural experiment stations, extension services, and other agencies in 14 cotton-growing States, the United States Department of Agriculture, and the National Cotton Council of America. The statements in this report were approved and adopted by the following conferees:

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